AD-A057 293 GILBERT ASSOCIATES INC READING PA F/G 13/2

NATIONAL DAM SAFETY PROGRAM. MIDVALE DAM (NJ-00205), PASSAIC RI--ETC(U)

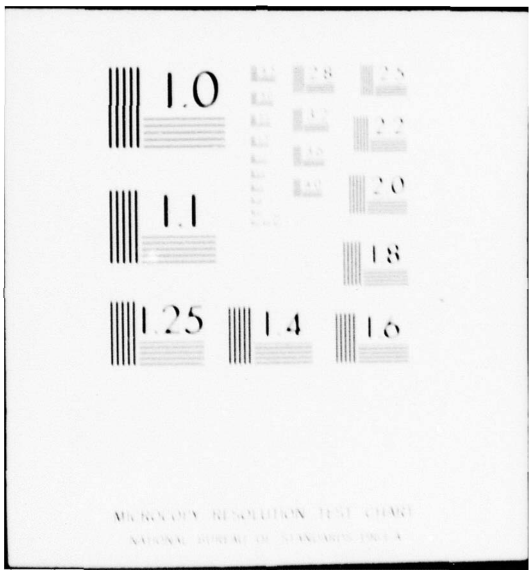
JUN 78 J A HAGEN DACW61-78-C-0114

UNCLASSIFIED NL

| OF |

AD
A057 293

END
DATE
FILMED
9-78
DDC


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

PASSAIC RIVER BASIN

PASSAIC COUNTY

NEW JERSEY

MIDVALE DAM

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

NJ 00205

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE - 2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

JUNE 1978

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NJ00205	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Phase I Inspection Report National Dam Safety Program Midvale Dam (NJ00205) Passaic County, New Jersey	5. TYPE OF REPORT & PERIOD COVERED 9 FINAL rept. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 James A. Hagen, P.E.	8. CONTRACT OR GRANT NUMBER(s) 15 DACW61-78-C-0114
9. PERFORMING ORGANIZATION NAME AND ADDRESS Gilbert Associates, Inc. P.O. Box 1489 Reading, Pa. 19603	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Philadelphia Custom House, 2d & Chestnut Streets Philadelphia, Pennsylvania 19106	12. REPORT DATE 11 June 1978 13. NUMBER OF PAGES 73 12 79p.
14. M Office) 6 National Dam Safety Program. Midvale Dam (NJ-00205), Passaic River Basin, Post Brook, Passiac County, New Jersey. Phase I Inspection Report.	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DI

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dams--N.J.
Midvale Dam. N.J.
National Dam Safety Program Phase I

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

08 10 007 JOB

154 858

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2 D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, New Jersey 08621

3 AUG 1978

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Midvale Dam in Passaic County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given on the first two pages of the report.

Based on visual inspection, available records, calculations and past operational performance, Midvale Dam is judged to be in fair condition. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. Engineering investigation and studies to evaluate the piping potential and static stability under Possible Maximum Flood (PMF) and ½ PMF on the dam's pervious section should be completed within nine months from the date of approval of this report. Remedial measures found necessary as a result of these investigations and studies should be initiated in calendar year 1979. In conjunction with these investigations and studies, piezometers should be installed in the dam's embankment and weirs installed to monitor the seepage flows from the dam's toe and left abutment.

b. Within three months from the date of approval of this report, trees should be removed from the dam's embankment and the area stabilized with suitable ground cover. Riprap at the toe of the dam should be stabilized and animal burrows in the embankment should be filled at the same time the trees are removed.

c. Operating officials of the dam should develop a periodic inspection program and maintenance manual for the dam within six months from the date of approval of this report.

NAPEN-D
Honorable Brendan T. Byrne

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman Robert A. Roe of the Eighth District. Under the provisions of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, thirty days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia, 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely yours,

Harry V Dutchyshyn

HARRY V. DUTCHYSHYN
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Cy furn:
Mr. Dirk C. Hofman, P.E.
Department of Environmental Protection

LEVEL II

Phase I Report
National Dam Safety Program

Name of Dam:	Midvale Dam
State:	New Jersey
County:	Passaic
USGS Quad Sheet:	Wanaque, N. J.
Coordinates:	N 41° 03' 18" LAT., E 74° 17' 34"
Stream:	None (Off the Wanaque River)
Dates of Inspection:	10-12 May 1978

The Midvale Dam is in fair condition as defined in Appendix H. Low to moderate amounts of clear water seepage was observed at the toe and left abutment, and the seepage was reputed to have been occurring for several years. The Probable Maximum Flood (PMF) and 1/2 PMF will cause the reservoir levels to be higher than the concrete core wall and impervious zone, and thus would aggravate the seepage condition significantly.

At the present, there were no observed indications that the dam is unstable. However, the future stability of the dam may be questionable due to an undesirable seepage condition. Additional investigation and studies on the embankment material and phreatic condition should be completed soon, in order to analyze the static stability of the dam and the resultant recommendations implemented as quickly thereafter as necessary.

Due to the age of the dam and the observations made during the inspection it is recommended that the operating officials develop an inspection program and prepare a maintenance manual for the dam. Trees should be removed from the embankment and animal burrows in the embankment should be filled.

JAMES A. HAGEN
REGISTERED
NO. 4766
DELAWARE
PROFESSIONAL ENGINEER

James A. Hagen

Based on visual inspection, available records, calculations and past operational performance, Midvale is judged to be in fair condition. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. Engineering investigation and studies to evaluate the piping potential and static stability under Possible Maximum Flood (PMF) and ½ PMF on the dam's pervious section should be completed within nine months from the date of approval of this report. Remedial measures found necessary as a result of these investigations and studies should be initiated in calendar year 1979. In conjunction with these investigations and studies, piezometers should be installed in the dam's embankment and weirs installed to monitor the seepage flows from the dam's toe and left abutment.

b. Within three months from the date of approval of this report, trees should be removed from the dam's embankment and the area stabilized with suitable ground cover. Rip-rap at the toe of the dam should be stabilized and animal burrows in the embankment should be filled at the same time the trees are removed.

c. Operating officials of the dam should develop a periodic inspection program and maintenance manual for the dam within six months from the date of approval of this report.

APPROVED: Harry V. Dutchyshyn
HARRY V. DUTCHYSHYN
Colonel, Corps of Engineers
District Engineer

DATE: 3 Aug 1978

May 1978

MIDVALE DAM

TABLE OF CONTENTS

1.0 PROJECT INFORMATION

1.1 GENERAL

1.1.1 Authority: Public Law 92-367, 8 August 1972, authorized the Secretary of the Army, through the U.S. Corps of Engineers to initiate a national program of safety inspections of non-federal dams in the United States. The Philadelphia Office of the Corps of Engineers has been assigned the responsibility of the inspection of these dams in the State of New Jersey. Gilbert Associates, Inc. has entered into a contract No. DACW61-78-C-0114, with the Philadelphia Office of the U.S. Corps of Engineers to inspect this dam, Gilbert Work Order 06-7249-000.

1.1.2 Purpose of Inspection: The purpose is to conduct a Phase I inspection according to the U.S. Corps of Engineers Recommended Guideline for Safety Inspection of Dams (Reference 1), as modified by contract requirements between Gilbert Associates, Inc. and the Corps of Engineers. The objective is to expeditiously identify those dams which pose an immediate threat to human life or property and to recommend future studies and/or any obvious remedial actions indicated by the inspection.

1.2 PROJECT DESCRIPTION

1.2.1 Dam and Appurtenances: Midvale Dam is a 42 foot high, 920 foot long, earthfill dam with, according to the drawings, a concrete core wall extending to the rock surface. There is a gravel road along the crest of the dam. There are no outlet provisions at this dam. Record drawing information is included at the end of this report. The water level is controlled at the Wanaque Overflow Weir (NJ 00214) which is a separate structure.

1.2.2 Location: Midvale Dam is located two blocks west of N.J. Route 511 in Midvale, N.J., and about one-half mile northeast of the Raymond Dam (see location map on page 12). Location of the dam is shown on the Geologic Map (Appendix F).

1.2.3 Size Classification: The dam is classified as a large structure because of its impoundment (78,000 acre-feet), in accordance with Section 2.1.1 of Reference 1.

1.2.4 Hazard Classification: The dam is located adjacent to Midvale, N.J. and upstream of a moderately populated floodplain. The dam is classified as a high hazard potential based on the requirements of Section 2.1.2 of Reference 1.

1.2.5 Ownership: The dam is owned and maintained by the North Jersey District Water Supply Commission (NJDWSC), a New Jersey state commission. They have engineering and maintenance facilities located at Raymond Dam in Wanaque, N.J. The Chief Engineer of the NJDWSC in Wanaque is Mr. Dean C. Noll. The address is:

North Jersey District Water Supply Commission
Ringwood Avenue
Wanaque, N. J. 07465

1.2.6 Purpose of Dam: The Midvale Dam serves as a saddle dam which closes off low topography in the rim of the Wanaque Reservoir. The reservoir supplies water to residents of Paterson, Passaic, Clifton, Montclair, Glen Ridge, Newark, Kearny and Passaic, New Jersey.

1.2.7 Design and Construction History: This dam was constructed from June 2, 1927 to April 28, 1928 by Winston & Company, Inc. of Kingston, N. Y., as part of the total Wanaque Project. The project began in 1920 and was completed with the reservoir being filled by March 4, 1929. The original design records could not be located by the staff of the NJDWSC at Wanaque. However, publications indicate the design was performed by employees of the NJDWSC with the assistance of individual consultants. The New Jersey Department of Environmental Protection (DEP) has several monthly progress inspection reports and photographs taken during construction. There is no indication of subsequent construction other than minor maintenance.

1.2.8 Normal Operational Procedures: There is no operational procedure for this dam. It relies on adequate freeboard to contain storm surges in the reservoir, with overflow handled by the Overflow Weir (see Location Map).

1.3 PERTINENT DATA

1.3.1 Drainage Area: 90.4 square miles

1.3.2 Discharge at Dam Site: Not Applicable

1.3.3 Elevation: (Feet above MSL)

Top of Dam - 310.0
Maximum Pool-Spillway Design Flood (SDF) Surcharge - 308.8 (see Section 5.0)
Full Flood control pool - Not Applicable
Recreation pool - Not Applicable
Spillway crest (gated) - Not Applicable
Upstream portal invert diversion tunnel - Not Applicable

Downstream portal invert diversion tunnel - Not Applicable
Streambed at centerline of dam - 268.0
Maximum tailwater - Not Applicable

1.3.4 Reservoir: Length of Maximum Pool - 6.6 miles

1.3.5 Storage (acre-feet):

Recreation Pool - Not Applicable
Flood Control Pool - Not Applicable
SDF Surcharge - 75,500
Top of Dam - 78,000

1.3.6 Reservoir Surface (acres):

Top of Dam - 2,620
SDF Surcharge - 2,590
Flood control pool - Not Applicable
Recreation pool - Not Applicable
Spillway Crest - with flashboards - 2,400
(at Overflow weir one mile to the south)

1.3.7 Dam: Type - earthfill with concrete core wall and impervious core.

Length - 920 feet
Height - 42 feet
Top Width - 15 feet
Side slope - U/S 2:1 (top) to 3:1 (lower part)
D/S 2:1 to 3:1 (toe)
Zoning - an impervious zone with side slope of 1:1 on the upstream side of the core wall; top elevation 300.0 feet
Impervious Core - concrete core wall with top elevation 305.0 feet and extending to sound rock. Also, see "Zoning" above.
Cutoff - A shallow cutoff in foundation rock formed by base of concrete core wall
Grout curtain - none (shallow foundation grouting for concrete corewall)

1.3.8 Diversion and Regulating Tunnel: Not Applicable

1.3.9 Spillway: Not Applicable

1.3.10 Regulatory Outlet: Not Applicable

2.0 ENGINEERING DATA

2.1 DESIGN

A plan, profile, grouting record, and maximum section through the dam are shown on original record tracings which are on file at the NJDWSC engineering office (contact Mr. Dean C. Noll) at Wanaque, N.J. (see Figure 2). No original design data were available other than results mentioned in the North East Water Works Association publication (Reference 3) and a 1925 report by the Commissioner of the NJDWSC (Reference 2).

2.2 CONSTRUCTION

Contract drawings, specifications, and record drawings, are available at the NJDWSC engineering office. Periodic inspection reports, news clippings, and photographs are available in dam application file number 32 at the New Jersey Department of Environmental Protection. They indicate that satisfactory quality construction work was performed on the project in general. Some work was performed during 1927. The majority of the construction was completed during the spring of 1928.

2.3 OPERATION - N.A.

2.4 EVALUATION

2.4.1 Availability: Foundation exploration and specific embankment data were incomplete. Design analysis data may not exist due to the early stage of technology at the time of construction. No record of seepage quantities has been made.

2.4.2 Adequacy: The design and construction data received or reviewed were adequate for use in this Phase I dam report. However, foundation exploration and embankment material data are insufficient for adequate safety analyses.

2.4.3 Validity: The specifications and record drawings appear to be consistant with observed structure.

3.0 VISUAL INSPECTION

3.1 FINDINGS

3.1.1 General: The Phase I dam inspection was performed during the period May 10-12, 1978. The inspection was part of a National Dam Safety Program administered by the U.S. Army Corps of Engineers. A previous inspection of this dam was performed on 5 April 1977 by employees of the NJDWSC and is attached as Appendix E.

3.1.2 Dam: The materials exposed on the downstream slope are sand, silty sand, and gravel. Some sandy silt was seen near the toe of the embankment and beyond the toe area. The downstream slopes were generally uniform with minor surface sloughing near the toe area, and were adequately covered with protective vegetation. At least two large trees below and near the toe were gently leaning away from the dam. One tree, near the path of the flowing water, was recently tipped on its side and uprooted, but is still maintaining vigorous new foilage.

Seepage at the left abutment emerges from about elevation 267 and extends to the toe. The total seepage from the area was estimated at 30 to 50 gallons-per-minute at a collection ditch near the security fence, about 50 ft beyond the toe area. Recorded on May 11, 1978 when the reservoir was at elevation 301.5. On May 25, after heavy rainfall the previous day and with a pool elevation of 303, the seepage and runoff were estimated at 80 to 100 gpm. The flow collected from several areas along the toe. A large, saturated zone was present at and above the toe of the dam indicating that seepage was occurring through the embankment. A seepage condition around the right side of the toe area was obscured by a granular fill recently placed over the area, apparently for insect control. Piping or boiling was not observed within this fill area. All seepage flows were clear at the time of inspection. For a sketch of the seepage areas see Figure 3. NJDWSC personnel stated that it is not known when seepage started, but that the first official reference to the seepage is contained in a report dated May 3, 1976 (page E-4 of Appendix E).

3.1.3 Appurtenant Structures: The only appurtenant structure is a concrete bulkhead as shown on Figure 3. Seepage water was not flowing from this structure at the time of the inspection.

3.1.4 Reservoir Area: Some areas of riprap have been dislodged, three holes in the embankment between stones were noticed. They ranged up to six inches in diameter and appeared to have been either locations of removed trees or burrows dug by animals. The reservoir rim near the dam site appears to have stable slopes. The Highland Precambrian rocks are fully exposed along the shore. The area is densely wooded.

3.1.5 Downstream Channel: Shallow erosion gullies have developed over the relatively flat toe area in response to seepage flow downhill to a collection ditch near the property fence.

3.2 EVALUATION

The visual evidence, including the relatively small quantity of clear seepage, relatively uniform downstream slopes, a lack of piping or boiling phenomena in the seepage area, and a history of seepage have led to the conclusion that the dam is not in an imminently dangerous condition. Nevertheless, the occurrence of seepage at and above the toe area causes necessary concern with regard to future safety of the many residents living below the dam. Therefore, further investigation is required to make adequate stability and seepage analyses, as discussed in Section 7.0. Several large trees growing on the lower part of the embankment slope pose a threat of penetration into the dam and future seepage along decayed root holes.

3.3 ATTENDEES

North Jersey District Water Supply Commission
Mario Di Laura

New Jersey Department of Environmental Protection
Larry Woscyna

Gilbert Associates, Inc.
James A. Hagen
Rudolph J. Wahanik
Fine T. Hsu

4.0 OPERATIONAL PROCEDURES

4.1 PROCEDURES

The water level in Wanaque Reservoir is contained by the Overflow Weir structure one mile away to a pool elevation of 302.4 feet MSL. The high water elevation recorded since October 1950 was 303.93 feet (Reference 6 and 7) with excess flow passing over the uncontrolled weir. There is no operational procedure at Midvale Dam.

4.2 MAINTENANCE OF DAM

The reservoir rim is traversed daily by NJDWSC guards who report apparent maintenance problems to the Chief Engineer. In addition, periodic inspections are made by engineers and/or other personnel of the NJDWSC and reports written regarding maintenance requirements. The 1977 inspection report (Appendix E) recommended removal of trees on the reservoir side of the dam. The trees were apparently removed subsequent to the inspection. The NJDWSC has foresters employed to cut trees and otherwise maintain the woodlands on their property. Attempts have been made to deal with the toe seepage at the dam by covering one area with a free draining gravel and by pouring concrete in another area.

4.3 MAINTENANCE OF OPERATING FACILITIES - N.A.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

No automatic warning systems exist at this dam. A daily patrol is made by the NJDWSC security guards equipped with radios. According to NJDWSC personnel, the guards are instructed to radio the guard house, or failing that, to directly radio the Wanaque police of any obvious, impending hazard to residents from the dams on the Wanaque Reservior.

4.5 EVALUATION

The maintenance procedures for this dam are generally adequate except as indicated in this report. However, some additional maintenance work is required on the riprap and on the downstream toe of the embankment.

5.0 HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

Other than the dam, there are no hydraulic structures or control facilities at this location. Reservoir overflow is provided by the Overflow Weir, one mile to the south. A summary of hydrologic data and the methodology used in this report is contained in Appendix D.

5.1.1 Design Data

The maximum pool elevation for the design discharge of 18,000 cfs is 304.3 feet, based on a spillway elevation of 300.3 feet plus a head of 4.0 feet, for the Overflow Weir. With the flashboards in place, the Overflow Weir becomes a sharp edged weir with an elevation of 302.4 feet, and a pool elevation of 306.6 feet with the design flow of 18,000 cfs.

5.1.2 Experience Data

The maximum recorded reservoir level since October, 1950 is 303.9 feet, 6.1 feet lower than the crest of Midvale Dam. This level was reached in March, 1951 (see References 6 and 7).

5.1.3 Visual Observations

There is no visual evidence to indicate the dam has ever been overtopped.

5.1.4 Overtopping Potential

The PMF, when developed as described in Appendix D and with the flashboards in place at the Overflow Weir, results in a reservoir elevation of 308.8 feet. One-half of the PMF results in a reservoir elevation of 306.0 feet, with the flashboards in place. As discussed in Section 7.0, the PMF and 1/2 PMF reservoir levels are higher than the dam's concrete corewall.

5.1.5 Reservoir Drawdown

The existing emergency drawdown facilities installed in the several dams of the Wanaque Reservoir are not adequate to lower the water level of the reservoir in a short period of time. It is recommended that the owner designs and constructs water release structures that will allow lowering the water level within an acceptable period of time. A preliminary evaluation of the performance of the

existing drawdown facilities is given in Appendix D. The time required to drawdown the Midvale Dam from elevation 302.4 to the dam's base level of 268 feet using the existing facilities at Raymond Dam is:

System in Use	Time in Days
Aerator System	144
36" Diameter Blowoff	445
Aerator and Blowoff	108

6.0 DAM STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

6.1.1 Visual Observations: Seepage emanates from the toe and left abutment areas, as discussed in Section 3.1.2. The seepage apparently is not indicative of a present instability but must be assumed to pose a threat to the future integrity of the dam by possible piping and/or erosion. This threat must be assumed because adequate assessment cannot be made due to the lack of detailed information on the composition of the dam and flow characteristics through the dam and foundation.

6.1.2 Design and Construction Data: The record drawings indicate that the concrete core wall and the adjoining upstream impermeable zone extend upward to elevation 305 feet and 300 feet, respectively. These elevations would be exceeded by the PMF (El. 308.8 feet) and 1/2 PMF (El. 306.0 feet) raising questions about the likelihood of erosion and piping of the downstream face, and subsequent instability of the embankment under these conditions.

The exact source and description of the impervious material used for this dam were not available. However, some simple soil classification, such as loam (L), clay (C), clay mixed with varying proportions of gravel and sand (CGS), etc., were used on the test boring logs for the borrow area of Wanaque Project.

No stability analyses were obtained for this dam and apparently none were performed. There are insufficient data on the composition of the dam, especially for assessing the potential for piping or erosion due to seepage.

6.1.3 Operating Records: The embankment slopes, according to an NJDWSC employee, have been stable during previous years. Other than seepage, which has been reported along the embankment toe for several years, no slope distress was registered in the reports reviewed during this inspection. There is no information on seepage flow quantities or flow conditions in the dam or its foundation.

6.1.4 Post Construction Changes: Except for minor maintenance items mentioned elsewhere, a comparison of the record drawings with the visual inspection data indicated no post-construction changes.

6.1.5 Seismic Stability: Although this dam is located within Zone 1 on the Algermissen Seismic Risk Map of the United States (1969 edition), there are questions with respect to the static stability of the dam, as set forth in 6.1.1, and, therefore, in accordance with paragraph 3.6.4 of Reference 1, seismic stability studies should be made for this dam if judged appropriate when considering results of future studies outlined in Section 7.1.4.

7.0 ASSESSMENT/REMEDIAL MEASURES

This assessment and remedial measures are subject to the conditions contained in Appendix H.

7.1 DAM ASSESSMENT

7.1.1 Safety: On the basis of the visual inspection and available record data, the dam does not show any major critical signs of distress such as slope failure, embankment cracking, boiling, internal erosion (piping) severe differential settlement, or large amounts of seepage flow. The seepage that occurs is clear and reportedly has occurred for several years. These factors indicate the dam is not in an imminently dangerous condition. However, the lack of detailed information on the composition of the embankment, flow conditions through the embankment and its foundation prevents complete assessment of future piping potential.

The dam crest will not be overtopped by the PMF or 1/2 PMF but, as discussed in Section 5.0, the PMF and 1/2 PMF reservoir levels will be higher than the concrete core wall and its adjoining upstream impervious zone. This raises additional questions about piping and/or erosion and subsequent instability of the dam.

Trees near the toe of the dam may cause an increase in seepage in the future if their root systems penetrate deep into the embankment and subsequently decay.

7.1.2 Adequacy of Information: The visual inspection generally verifies the overall geometry of the dam as presented in record drawings.

There is insufficient information on the composition of the dam and flow characteristics in the embankment and its foundation. There are no quantity records for the seepage. There is no stability analysis for the design condition, the present condition of seepage, or the PMF or 1/2 PMF condition. This information is needed for assessing the future stability of the dam.

7.1.3 Urgency: The additional studies should be completed and the resultant recommendations implemented as quickly thereafter as necessary.

7.1.4 Necessity for Further Studies: Further studies are needed to better evaluate the piping potential and static stability of the dam under PMF and 1/2 PMF conditions, and to determine the proper remedial measures required. The minimum required studies are described in paragraphs 4.4.1, 4.4.2, 4.4.2.1, 4.4.3.2, 4.4.3.3, 4.4.3.4, 4.4.3.5 and 4.4.3.6 in Appendix I.

Piezometers should be installed in the embankment and weirs should be installed at the surface. Seepage flow over the weirs should be measured at least once a week, preferably once a day.

Due to the age of the dam and the observations made during the inspection, it is recommended that the operating officials develop an inspection program and prepare a maintenance manual for the dam.

7.2 REMEDIAL MEASURES

7.2.1 Alternatives: No viable alternatives to the studies outlined in Section 7.1.4 have been identified.

7.2.3 Operational/Maintenance Procedures: The seepage should be observed frequently for cloudy or muddy flows which would indicate internal erosion (piping). Such a condition would be indicative of a rapidly deteriorating dam, and should be regarded as a potential threat to safety.

Trees should be cut and should be prevented from becoming re-established.

Burrows developed in the embankment face should be properly repaired.

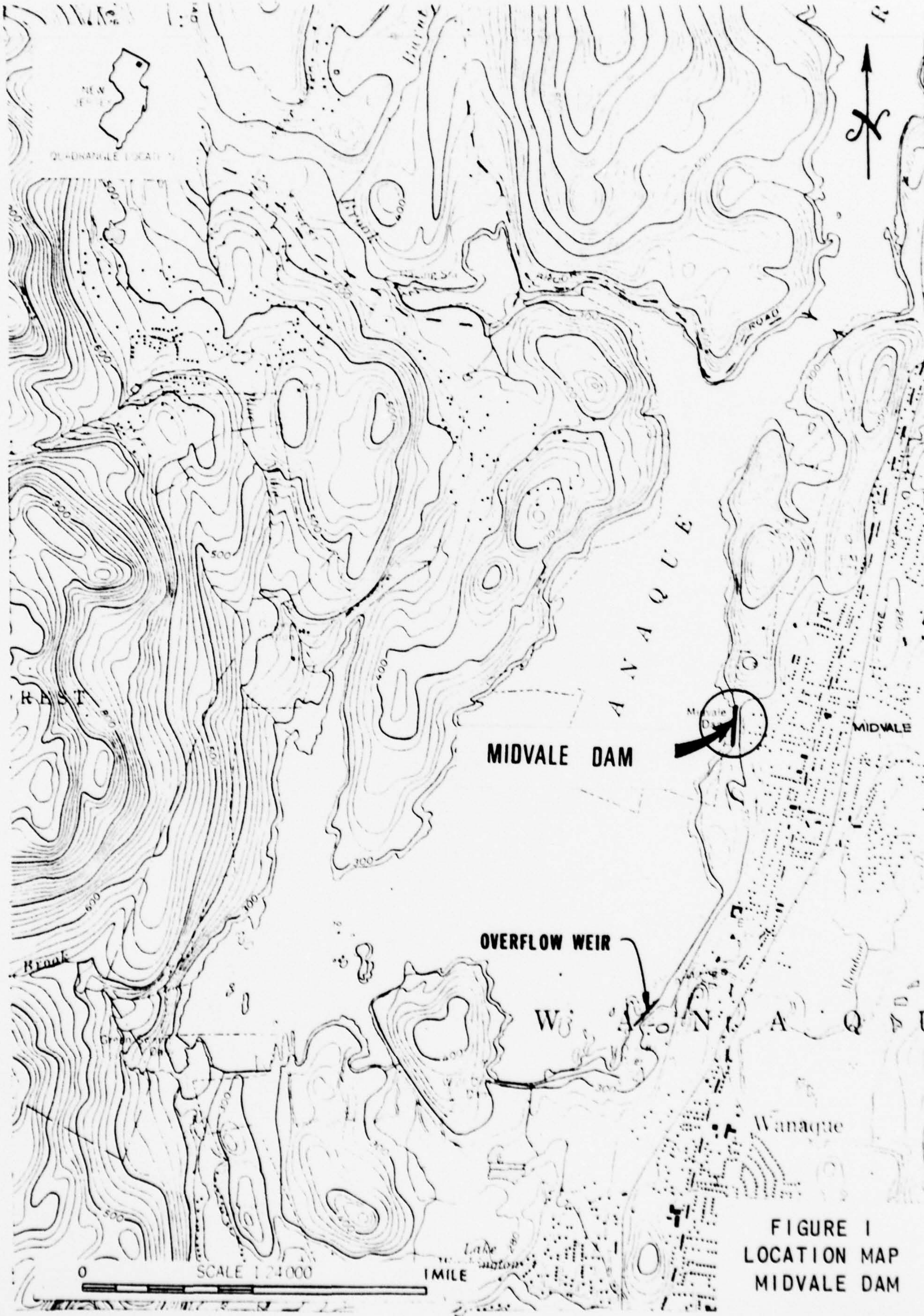
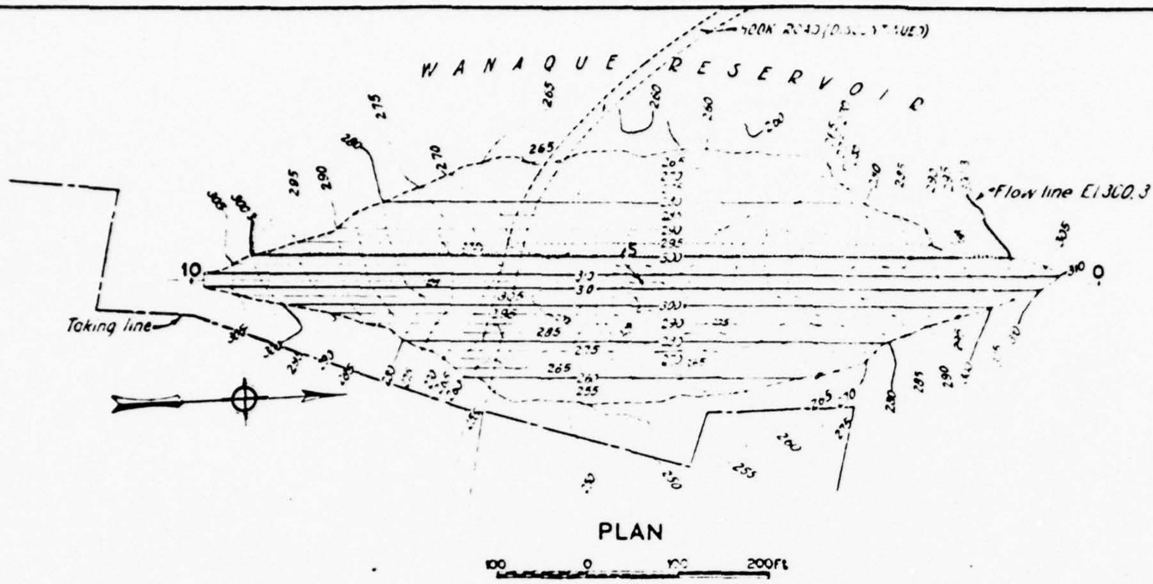
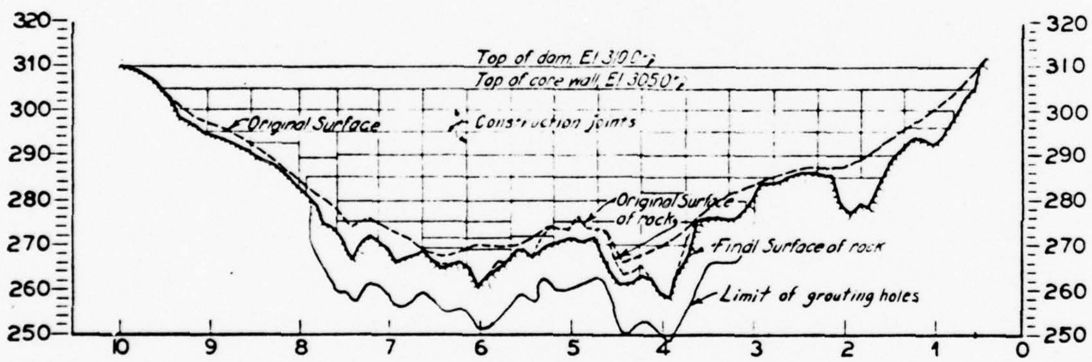


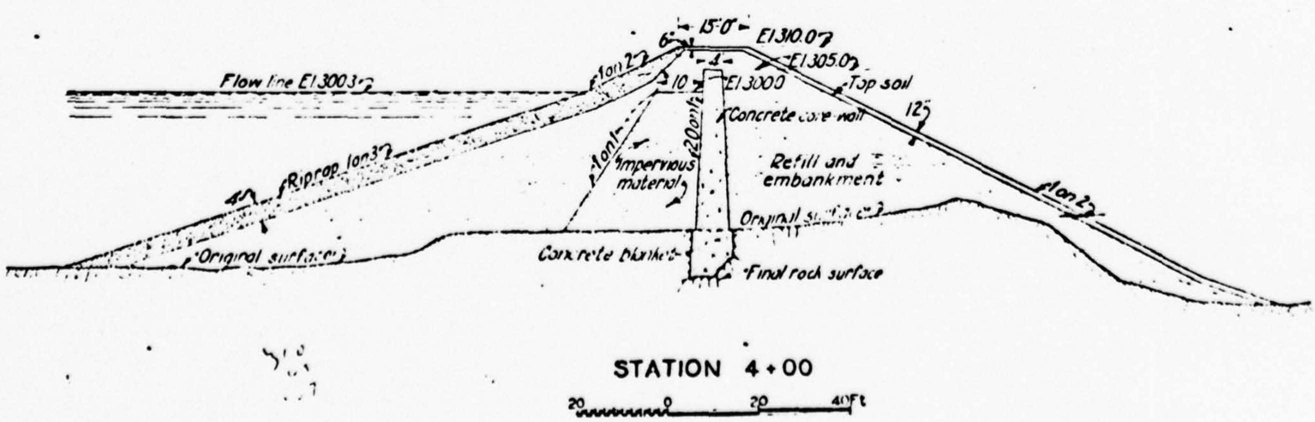
FIGURE 1
LOCATION MAP
MIDVALE DAM



PLAN



PROFILE



STATION 4+00

HOLE NO	STA	ROCK AT ELEV	DEP
1	3+00	[illegible]	[illegible]
2	3+10	[illegible]	[illegible]
3	3+20	275.9	[illegible]
4	3+30	[illegible]	[illegible]
5	3+40	[illegible]	[illegible]
6	3+50	[illegible]	[illegible]
7	3+60	275	[illegible]
8	3+70	267.5	[illegible]
9	3+80	264.3	[illegible]
10	3+90	258.3	[illegible]
11	4+00	259.4	[illegible]
12	4+10	262.9	[illegible]
13	4+20	263.2	[illegible]
14	4+30	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	4+56.5	[illegible]	[illegible]
17	4+72	271.6	[illegible]
18	[illegible]	[illegible]	[illegible]
18A	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]
21	5+20	[illegible]	[illegible]
22	5+30	[illegible]	[illegible]
23	5+40	[illegible]	[illegible]
24	5+50	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]
26	5+70	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]
28	5+90	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]
31	6+20	[illegible]	[illegible]
32	6+30	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]
34	5+50	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]
36	6+70	267.8	[illegible]
37	6+80	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]
39	7+00	259.4	[illegible]
40	[illegible]	270.9	[illegible]
41	7+20	272.4	[illegible]
42	7+30	[illegible]	[illegible]
43	7+40	[illegible]	[illegible]
44	7+50	[illegible]	[illegible]
45	[illegible]	273.9	[illegible]
46	[illegible]	[illegible]	[illegible]
47	7+80	[illegible]	[illegible]
48	[illegible]	[illegible]	[illegible]
Total			472

NOTE: Hard rock er
is 1ft left of

Const
under
Kingsl
this f

Drawn
Traced JOH, EEC
Checked

RECORD DRAWING
SHEET 52 SHEETS IN SET 61

GROUTING RECORD

HOLES						TEST		GROUTING			
HOLE NO	STA	ROCK AT ELEV	DEPTH	WATER AT ELEV	DEPTH OF SEAM	WATER PRESSURE (LBS PER SQ IN)	LEAKAGE (GALS PER MINUTE)	PRESSURE (LBS PER SQ IN)	CEMENT USED (BAGS)	GROUT USED (GALS)	REMARKS
1	3+00	[illegible]	9½	2723	0	[illegible]	0	75	4	24	
2	3+10	[illegible]	9½	2682	0	55	20TS				LEAKAGE AT CONNECTIONS
3	3+20	275.9	10	2689	3	50	4	85	½	12	
4	3+30	[illegible]	10		10	55	20TS				LEAKAGE AT CONNECTIONS
5	3+40	[illegible]	10			53	1				
6	3+50	[illegible]	10			55	0				
7	3+60	275	10			58	0				
8	3+70	267.5	10			70	0				
9	3+80	264.3	10			63	0				
10	3+90	258.3	10	2517		65	0	90	½	26	WATER TEST SHOWED CONNECTION BUT
11	4+00	259.4	10	2505		25	12	90	½	15¾	GROUT DID NOT PASS BETWEEN HOLES.
12	4+10	262.9	10	2507		59	0	90	½	12	
13	4+20	263.2	10	2570		50	2½	90	½	12	
14	4+30	261.8	10	2622		10	15	90	8	83	WATER TEST SHOWED CONNECTION BUT
15	4+41.5	[illegible]	11	[illegible]		26	12	90	1	16½	GROUT DID NOT PASS BETWEEN HOLES
16	4+56.5	264.55	10	2605.5		5	15	90	7	78	
17	4+72	271.6	9½	2637	2	33	13	90	3	25	
18	4+77.5	[illegible]	4½		0	53	2				
18A	[illegible]	[illegible]	8	2642	2	60	1	90	1	9	
19	5+15	[illegible]	10	2625		60	1	90	1	10½	
20	5+10	[illegible]	10		8½	20	13	90	1	12½	
21	5+20	[illegible]	10			58	0				
22	5+30	[illegible]	9½			60	20TS				LEAKAGE AT CONNECTIONS
23	5+40	[illegible]	10	2656		62	0	90	1	10	
24	5+50	[illegible]	10	2647		60	3½	90	1	3	SMALL OUTFLOWS IN MANY SEAMS AROUND HOLE
25	5+60	[illegible]	10	2650		60	0	90	2	15	
26	5+70	[illegible]	10	2678	8	10	15	90	6	69½	CONNECTED, DISTURBANCE IN EACH ONE
27	5+80	[illegible]	10	2653	0	65	0	90	2	13½	AHEAD WHEN GROUTING
28	5+90	[illegible]	10	2633	6	10	10	90	7	79	
29	6+00	[illegible]	[illegible]	2539	10	65	0	90	1	7	
30	6+10	[illegible]	10	2625	8	50	9	90	4	54½	
31	6+20	[illegible]	11	2623	3½	10	14	90	½	4	CONNECTED
32	6+30	[illegible]	10	2619	4½	15	15				GROUTED FROM No.30
33	6+40	264.7	10		10	62	0				
34	6+50	[illegible]	10½		7½	60	0				
35	6+60	[illegible]	10		6½	60	0				
36	6+70	267.8	10		0	60	0				
37	6+80	267.4	9½		0	60	0				
38	6+90	[illegible]	10½		8	60	0				CONNECTED WITH No 40
39	7+00	259.4	10	2694	4	25	12	90	1	22½	OUTFLOW FROM AND AROUND HOLE
40	7+10	270.9	10	2648	6	12	15	90	½	3	GOOD STREAM FLOWING FROM HOLE
41	7+20	272.4	10	2709	0	10	13	90	4	50	GROUT DID NOT PASS BETWEEN HOLES
42	7+30	[illegible]	10	2625	0	32	2	85	4	52	
43	7+40	[illegible]	10	2644	0	40	20TS	95	1½	16½	
44	7+50	[illegible]	10	2641	7	50	6	85	1	5	
45	7+60	273.9	11	2704	0	2	15	90	4½	70½	CONNECTED
46	7+70	[illegible]	9½	2709	4	45	7	90	1	16	
47	7+80	[illegible]	9½		4	55	0	85	½	12	
48	7+90	[illegible]	9½		7	30	1	85	½	5½	
Total			472½				246¾		67	871½	

NOTE: Hard rock encountered in all holes. Holes are on center line except No 6 and No. 14 which are 1ft right of ℄, and No 35 which is 1ft left of ℄

CONSTRUCTION RECORD
Constructed June 3 1927 to Apr 18 1928, under Contract 18, [illegible] & Co. Inc, Kingston, N.Y. Contractor, as shown on this record drawing

[illegible signature]
Engineer in charge

NORTH JERSEY DISTRICT
WATER SUPPLY COMMISSION

WANAQUE RESERVOIR

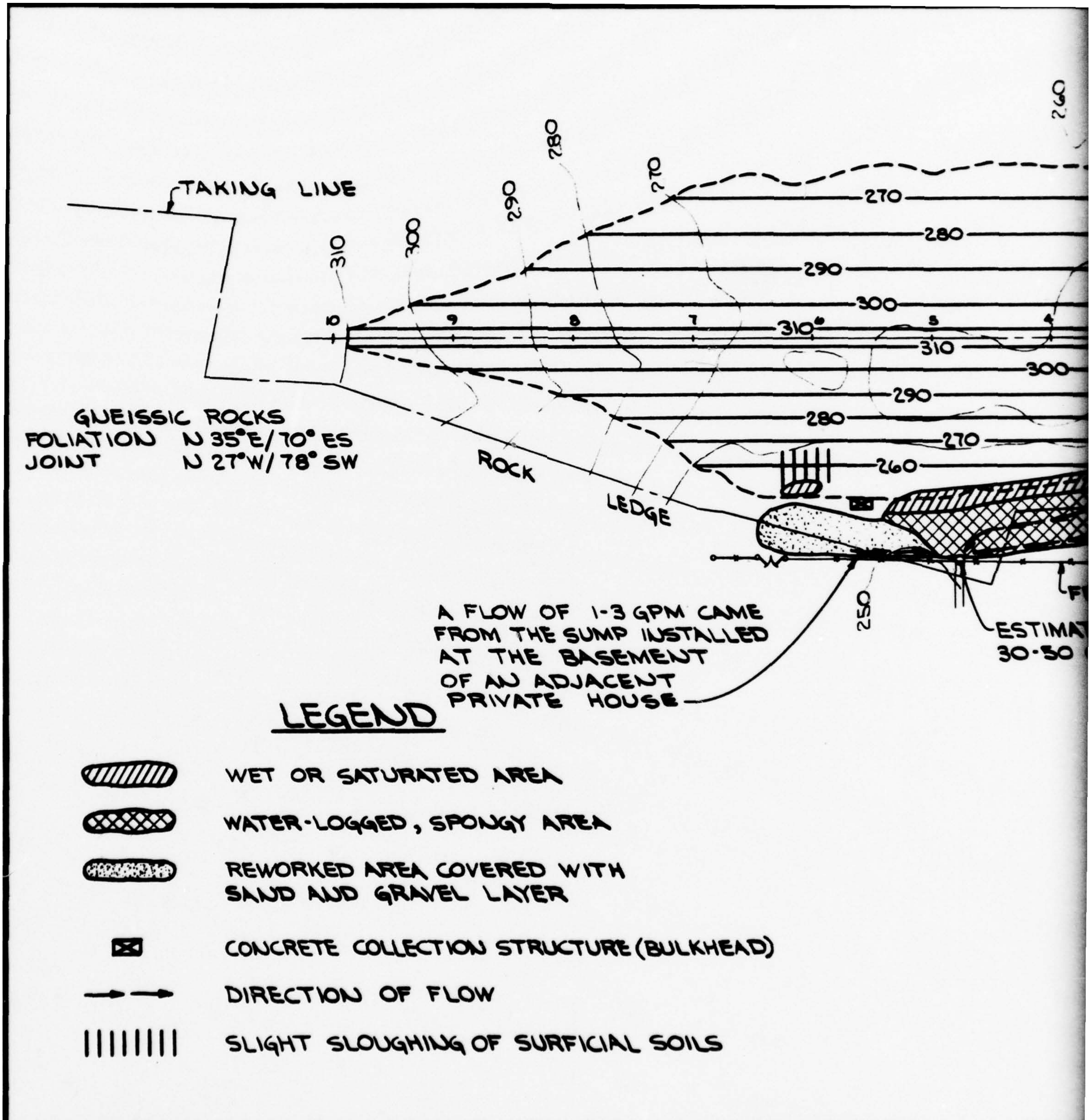
MIDVALE DAM
PLAN, PROFILE AND SECTION

APRIL 30, 1931

FIGURE 2

CASE DR. 12 File-3.42Wm Acc. 3252

2



TAKING LINE
310
300
290
280
270
260
250
10
9
8
7
6
5
4
GNEISSIC ROCKS
FOLIATION N 35°E/70° ES
JOINT N 27°W/78° SW
ROCK
LEDGE
A FLOW OF 1-3 GPM CAME FROM THE SUMP INSTALLED AT THE BASEMENT OF AN ADJACENT PRIVATE HOUSE
ESTIMAT
30-50
LEGEND
WET OR SATURATED AREA
WATER-LOGGED, SPONGY AREA
REWORKED AREA COVERED WITH SAND AND GRAVEL LAYER
CONCRETE COLLECTION STRUCTURE (BULKHEAD)
DIRECTION OF FLOW
SLIGHT SLOUGHING OF SURFICIAL SOILS

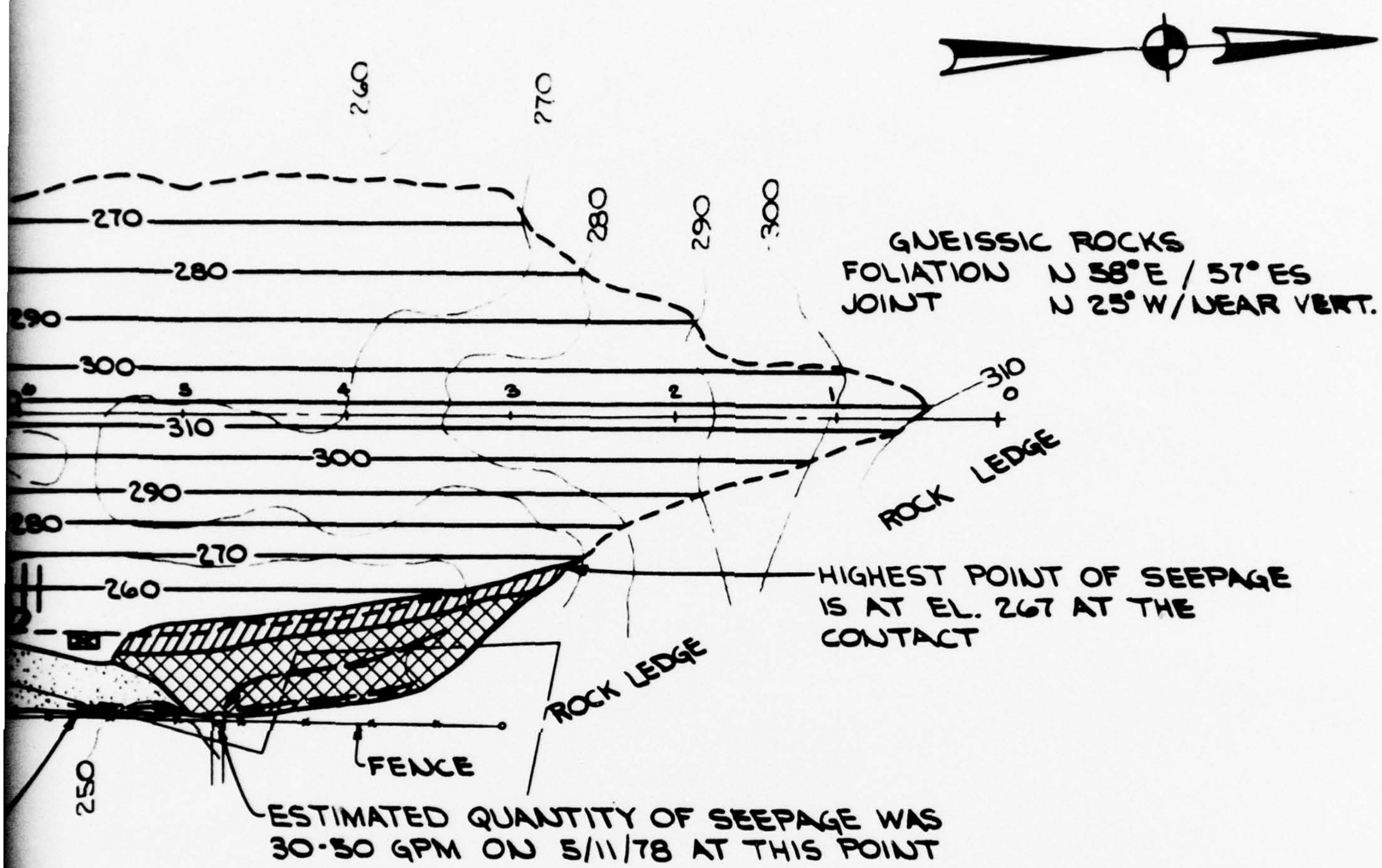


FIGURE 3

PLAN VIEW
MIDVALE DAM
SEEPAGE AREAS
NOT TO SCALE

APPENDIX A

VISUAL CHECKLIST

APPENDIX A - VISUAL INSPECTION CHECK LIST
PHASE 1

Name Dam: Midvale   County: Passaic   State: New Jersey   Coordinators: Philadelphia District-Corps of Engineers

Date(s) Inspection: 10-12 May, 1978   Weather: Clear   Temperature: 58^o

Pool Elevation at Time of Inspection: 301.5 MSL   Tailwater at Time of Inspection: Not Applicable

Inspection Personnel:
Gilbert Associates, Inc.

Fine T. Hsu
James A. Hagen
Rudolph J. Wahanik

Also Present:

Mario DiLaura (NJDWSC)
Larry Woscyna (NJDEP)

James A. Hagen - Recorder

CONCRETE/MASONRY DAMS

(Midvale Dam is Earthfill with a Concrete Core)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEEPAGE OR LEAKAGE	Not Applicable	
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	Not Applicable	
DRAINS	Not Applicable	
WATER PASSAGES	Not Applicable	
FOUNDATION	Not Applicable	

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	Not Applicable	
STRUCTURAL CRACKING	Not Applicable	
VERTICAL AND HORIZONTAL ALIGNMENT	Not Applicable	
MONOLITH JOINTS	Not Applicable	
CONSTRUCTION JOINTS	Not Applicable	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	Surface cracks were not observed on the crest or the downstream slope.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	Although there is no visible unusual slope movement or cracking at or beyond the toe, leaning of two large trees at the toe near the centerline of dam, at angles of 7^o to 8^o from the vertical, may suggest a slow and progressive slope creep in the past.	All trees growing at the toe or above the toe should be cut to avoid root systems spreading into the embankment.
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	A minor local surface sloughing area was observed along the embankment near the toe below the right abutment.	The local surface sloughing may reflect the variation in embankment material composition and differentiation in erodability.
VERTICAL AND HORIZONTAL ALINEMENT OF THE CREST	Vertical and horizontal alignment of the crest is in good order.	
RIPRAP FAILURES	Riprap failures were not observed.	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	The contact between the embankment and abutments was generally in good condition. A tree line was formed along the contact between the left abutment and the downstream embankment slope.	
ANY NOTICEABLE SEEPAGE	Seepage had developed along the downstream toe of the left abutment below elevation 267 ft. Seepage flow at the point of discharge about 50 ft beyond the toe near the centerline of the dam was measured to be between 30 to 50 gpm. A large low area, 50 to 55 ft in width beyond the toe was saturated, water logged and very soft. A wet condition was also often found some distance above the toe below the downstream abutments.	The seepage condition presents a potential safety hazard, it is recommended that a further study be made with regard to the safety aspect of the seepage.
STAFF GAGE AND RECORDER	None at this dam.	
DRAINS	Drainage at the toe area was poor.	A method of effective toe drainage should be devised during further study.

OUTLET WORKS - (NONE DESIGNED OR OBSERVED)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	Not Applicable	
INTAKE STRUCTURE	Not Applicable	
OUTLET STRUCTURE	Not Applicable	
OUTLET CHANNEL	Not Applicable	
EMERGENCY GATE	Not Applicable	

UNGATED SPILLWAY - (NONE WAS OBSERVED)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Not Applicable	
APPROACH CHANNEL	Not Applicable	
DISCHARGE CHANNEL	Not Applicable	
BRIDGE AND PIERS	Not Applicable	

GATED SPILLWAY - (NONE WAS OBSERVED)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	Not Applicable	
APPROACH CHANNEL	Not Applicable	
DISCHARGE CHANNEL	Not Applicable	
BRIDGE AND PIERS	Not Applicable	
GATES AND OPERATION EQUIPMENT	Not Applicable	

INSTRUMENTATION

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None Observed	
OBSERVATION WELLS	None Observed	
WEIRS	None Observed	
PIEZOMETERS	None Observed	
OTHER	None Observed	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	The slopes around this part of the reservoir rim range from gentle to steep, and are formed by gneissic rock masses with little soil cover. The bank is also covered with woods or vegetation.	
SEDIMENTATION	Due to the geologic environment of Precambrian Highlands, little soil cover in this region, and good vegetation cover around the reservoir, the amount of sedimentation deposited in the reservoir should be minimal and progress at a very slow rate.	

APPENDIX B

ENGINEERING DATA CHECKLISTS

APPENDIX B
CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
PLAN OF DAM	A tracing of the record drawing is available at the North Jersey District Water Supply Commission office in Wanaque, N.J. (hereafter referred to as NJDWSC-W)
REGIONAL VICINITY MAP	The USGS Wanaque, N.J. 7-1/2 min. quadrangle map is available.
CONSTRUCTION HISTORY	The 1925 Commissioner's Report (Reference 2) is available at NJDWSC-W. There is also a 1930 and a 1931 Commissioner's report at NJDWSC-W, an article on the construction was printed in the N.E.W.W.A. Journal (Reference 3) during construction. Some photos are available in the NJDWSC-W and the N.J. Dept. of Environmental Protection offices in Trenton, N.J. (DEP).
TYPICAL SECTIONS OF DAM	A section through the dam is shown on record drawing No. 52 of 61 which is available at NJDWSC-W (see Figure 2 of this report).
HYDROLOGIC/HYDRAULIC DATA	Records are available at NJDWSC-W and some are printed in USGS reports.
OUTLETS - PLAN	Not Applicable
- DETAILS	Not Applicable
- CONSTRAINTS	Not Applicable
- DISCHARGE RATINGS	Not Applicable
RAINFALL/RESERVOIR RECORDS	Excellent records are available from the USGS and NJDWSC from the time of construction of this dam.

APPENDIX B
CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
DESIGN REPORTS	Design reports are not available; however, a brief description of the dam design can be found in the North Jersey District Water Supply Commission's Report 1925. (Reference 2)
GEOLOGY REPORTS	Geologic reports of this dam site are not available.
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	Design calculations, dam stability, or seepage studies were not available at NJDWSC-W. Complete original design calculations for this dam do not appear to be in the DEP files.
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	Impervious borrow materials for the Wanaque reservoir project were investigated as shown on drawings sheet 7 (Contract 2A), sheet 3 (Contract 7), sheets 10, 11, and 12 (Contract 2), including test boring data available at the NJDWSC-W. Test borings at the foundation area of the dam were not available. Foundation grouting records were shown in Drawing sheet 52 in set 61. Laboratory tests were not reported.
POST-CONSTRUCTION SURVEYS OF DAM	See Record Drawing Sheet 52 in set 61 showing as-built section, profile, and plan (see page 13 of this report).
BORROW SOURCES	All impervious materials required for constructing the impervious layer upstream apparently came from the original nearby flood plains prior to their submergence. Scattered borrow areas encircled by Midvale, Raymond, and Wolf Den Dams were shown in Drawing Sheet 3 in Set 31, Contract 7.

APPENDIX B
CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
SPILLWAY PLAN	
SECTIONS	Not Applicable
DETAILS	
OPERATING EQUIPMENT PLANS & DETAILS	Not Applicable
MONITORING SYSTEMS	None observed.
MODIFICATIONS	No modifications from the design of the dam were observed.
HIGH POOL RECORDS	Records exist at the NJDWSC-W and USGS publications.
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Annual reports for certain years are in dam file No. 32 of DEP.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None reported.
MAINTENANCE OPERATION RECORDS	Operational levels of the reservoir are available from NJDWSC-W.

APPENDIX B - CONT'D

CHECK LIST
ENGINEERING DATA
HYDROLOGIC AND HYDRAULIC DATA

DRAINAGE AREA CHARACTERISTICS: Densely forested, very hilly with minimal cover on bedrock.

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 302.4

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): Not Available

ELEVATION MAXIMUM SPILLWAY DESIGN FLOOD POOL: 308.8

ELEVATION TOP OF DAM: 310.0

CREST: Cleared roadway

a. Elevation: 310.0
b. Type: Non-overflow
c. Width: 15 feet
d. Length: 920 feet
e. Location Spillover: Reservoir spillway about one mile south
f. Number and Type of Gates: Not Applicable

OUTLET WORKS: Non-overflow

a. Type: Not Applicable
b. Location: Not Applicable
c. Entrance inverts: Not Applicable
d. Exit inverts: Not Applicable
e. Emergency draindown facilities: See Appendix D

HYDROMETEOROLOGICAL GAGES:

a. Type: Rainfall recording chart, 24 hour precipitation can, and maximum and minimum temperature recorder. Float type continuous stream level recorder with drum chart.

b. Location: Raymond Dam in Wanaque, New Jersey.

c. Records: Weather data published as climatological Data-Wanaque-Raymond Dam by the National Oceanic and Atmospheric Administration. Streamflow data is recorded by the U.S.G.S.

MAXIMUM NON-DAMAGING DISCHARGE: Non-overflow

APPENDIX C

PHOTOGRAPHS

May 1978

VIEW OF TOE AREA. NOTE WATER IN FOREGROUND

May 1978

VIEW FROM UPPER RIGHT ABUTMENT

May 1978

VIEW OF TOE FROM UPPER LEFT ABUTMENT

APPENDIX D

RESERVOIR HYDROLOGY AND DRAWDOWN

APPENDIX D

RESERVOIR HYDROLOGY AND DRAWDOWN

Reservoir Hydrology

The hydrologic analysis presented in this Report and in this Appendix pertains to present hydrologic conditions and does not consider future changes produced by uncertain conditions such as urbanization, forest fires, or other modifications within the watershed.

The inflow probable maximum flood hydrograph for Wanaque Reservoir was supplied by the Philadelphia Office of the Corps of Engineers (Reference 8) and is shown in Figure D-1. This hydrograph has a peak flow rate of 33,500 cfs occurring 50 hours after its start. The total runoff volume is 94,500 acre-feet, over a time span of 140 hours. The HEC-1 computer program (Refernece 5) was used to route this hydrograph through the reservoir. The main discharge structure for Wanaque Reservoir is a 520-foot long Overflow Weir about 1.0 miles south of Midvale Dam, which has had permanent flashboards in place since 1934. The storage volume-spillway outflow relation was determined assuming that the initial water surface elevation was at the top of the flashboards (302.4) and the structure functions as a sharp-crested weir.

The spillway discharge and the reservoir storage/spillway outflow relationship used in HEC-1 for routing the PMF and one-half PMF through the reservoir assume the flashboards are in place. These relationships are in Figure D-2.

Water Elevation ft.	Spillway Discharge cfs	Reservoir Storage Acre-ft
302.4	0	0
303	820	1381
304	3760	3530
305	8410	5678
306	14210	7765
307	18640	9822
308	23700	12431
309	28900	14270
310	35300	16418

The surface area and storage of the Wanaque Reservoir at different water levels (Reference 2) are shown in Figure D-3. Their values are:

Water Elevation ft.	Surface Area Acre	Storage Acre-ft.
215	0	0
220	40	153
230	190	1228
240	370	4910
250	790	9820
260	1070	19027
270	1300	31303
280	1630	45420
290	1960	63326
300	2310	84701
310*	2620	106183
312*	2680	110480

*Values extrapolated from elevation 305.00 ft. (Reference 2).

Results of this routing procedure indicate that the PMF would raise the pool elevation to about 308.8 feet. Routing one-half the PMF (16,750 cfs) through Wanaque Reservoir raises the pool elevation to about 306.0 feet, 4 feet below the crest of Midvale Dam.

Flood routing was also performed assuming that the flashboards were removed. In this case, the storage volume-outflow relation was determined with the starting water surface elevation at the top of the spillway crest (300.3 feet) and the Overflow Weir discharging as an uncontrolled ogee crest spillway. HEC-1 results indicate that the PMF would raise the pool elevation to 306.9 feet. The Wanaque Reservoir Project was designed to safely discharge 18,000 cfs (slightly larger than one-half the PMF) without the flashboards in place. Graphs of pool elevation versus time for the PMF and one-half PMF routing, with and without flashboards, are found in Figures D-4 and D-5.

A summary of the flood routing flows through the Wanaque Reservoir and the corresponding water levels is given below.

a. With Flashboards

Flood Description	Inflow Peak cfs	Outflow Peak cfs	Pool Elevation ft.	Head Above Weir Crest ft.
PMF	33500	27900	308.8	6.40
One-half PMF	16750	14000	306.0	3.60

b. Without Flashboards

FLood Description	Inflow Peak cfs	Outflow Peak cfs	Pool Elevation ft.	Head Above Weir Crest ft.
PMF	33500	29100	306.3	6.00
One-half PMF	16750	13800	303.9	3.60

Reservoir Drawdown

If an emergency condition that affects the stability of one of several dams that form the Wanaque Reservoir or of the outlet and control works of the Raymond Dam develops, then a fast drawdown of the reservoir to a lower water level will be required. The lower water level depends on the location and nature of the hazardous condition. Figure D-6 shows graphically the times required to lower the reservoir level with the existing facilities. All drawdown times were computed considering an inflow rate of 2 cfs/square mile.

The water level in the Wanaque Reservoir can be lowered by means of:

a. The Wanaque Aqueduct System.

b. The existing aerator system.

c. A 36-inch diamter blowoff.

d. The blowoff and the aerator together.

e. Other blowoff lines.

All drawdown times were computed considering that the minimum inflow of 2 cfs/square mile into the reservoir was equalized by the system demand and other water loses.

A. <u>The Wanaque Aqueduct</u>

The potential of the Wanaque Aqueduct to lower the water level in the reservoir during an emergency condition is non-existant because a minimum inflow of 2 cfs/sq. mile, which is equivalent to 117 MGD, will supply the average daily demand of the distribution system. Table 1 gives the average water consumption during the last ten years.

Table 1

Year	Demand (MGD)
1967	95.37
1968	106.92
1969	111.17
1970	113.45
1971	112.88
1972	112.17
1973	103.09
1974	98.90
1975	92.07
1976	90.58
1977	107.90

B. Aerator System

Operation of the existing aerator system will drawdown the reservoir water level between the crest of the Overflow Weir at elevation 302.4 feet and the top of the aeration nozzles at elevation 240.5 feet in the following times:

Water Level (Feet)	Total Time (Days)
302.4	0
300	10.39
290	55.42
280	98.03
270	135.76
260	174.69
250	212.65
240.5	253.65

C. <u>36-Inch Diameter Blowoff</u>

The 36-inch diameter blowoff installed at the bottom of the Raymond Dam in the stream control conduits can be used to lower the reservoir level to an elevation of 222.00 which corresponds to the entrance intake sill of the lower conduit. The blowoff discharge is located at centerline elevation 213.38 feet. The times in days required by the blowoff line operating alone to lower the reservoir water level are:

Water Level (Feet)	Total Time (Days)
302.4	0
300	33.18
290	177.59
280	309.41
270	420.21
260	525.48
250	613.40
240	677.29
230	713.89
222	728.79

D. Blowoff and Aerator

Simultaneous operation of the 36-inch diameter blowoff pipe in conjunction with the aerator system will lower the reservoir water level in the following times:

Water Level (Feet)	Total Time (Days)
302.4	0
300	7.94
295	42.29
280	74.48
270	102.63
260	131.05
250	157.55
240	181.98
230	218.58
222	233.48

E. Other Blowoff Lines

Smaller diameter blowoff lines installed in several of the dams around the Wanaque Reservoir are not known to be in operable condition because, since its installation in 1925, the lines have not been inspected, operated, or maintained.

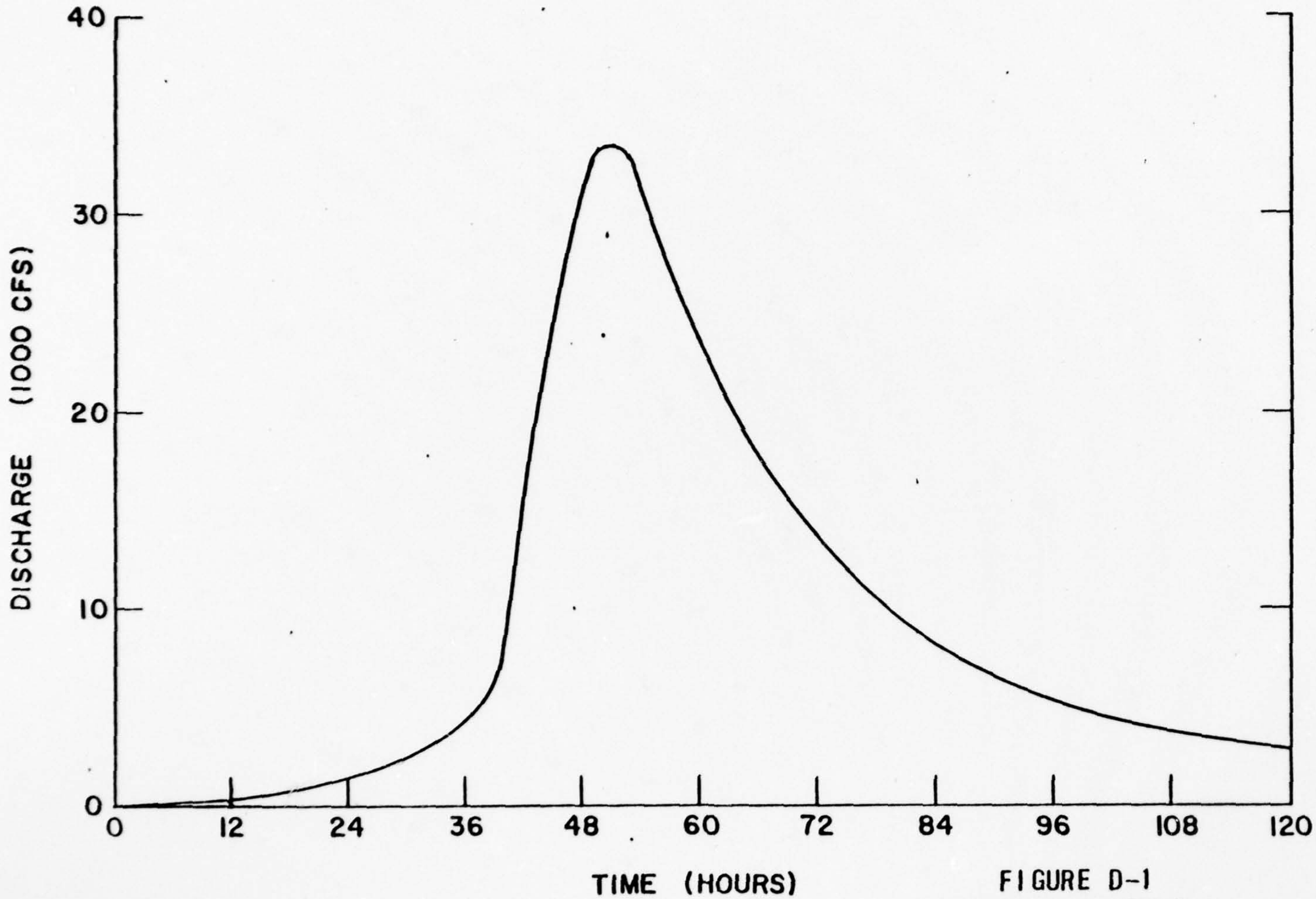


FIGURE D-1
WANAQUE RESERVOIR
PROBABLE MAXIMUM FLOOD
INFLOW HYDROGRAPH

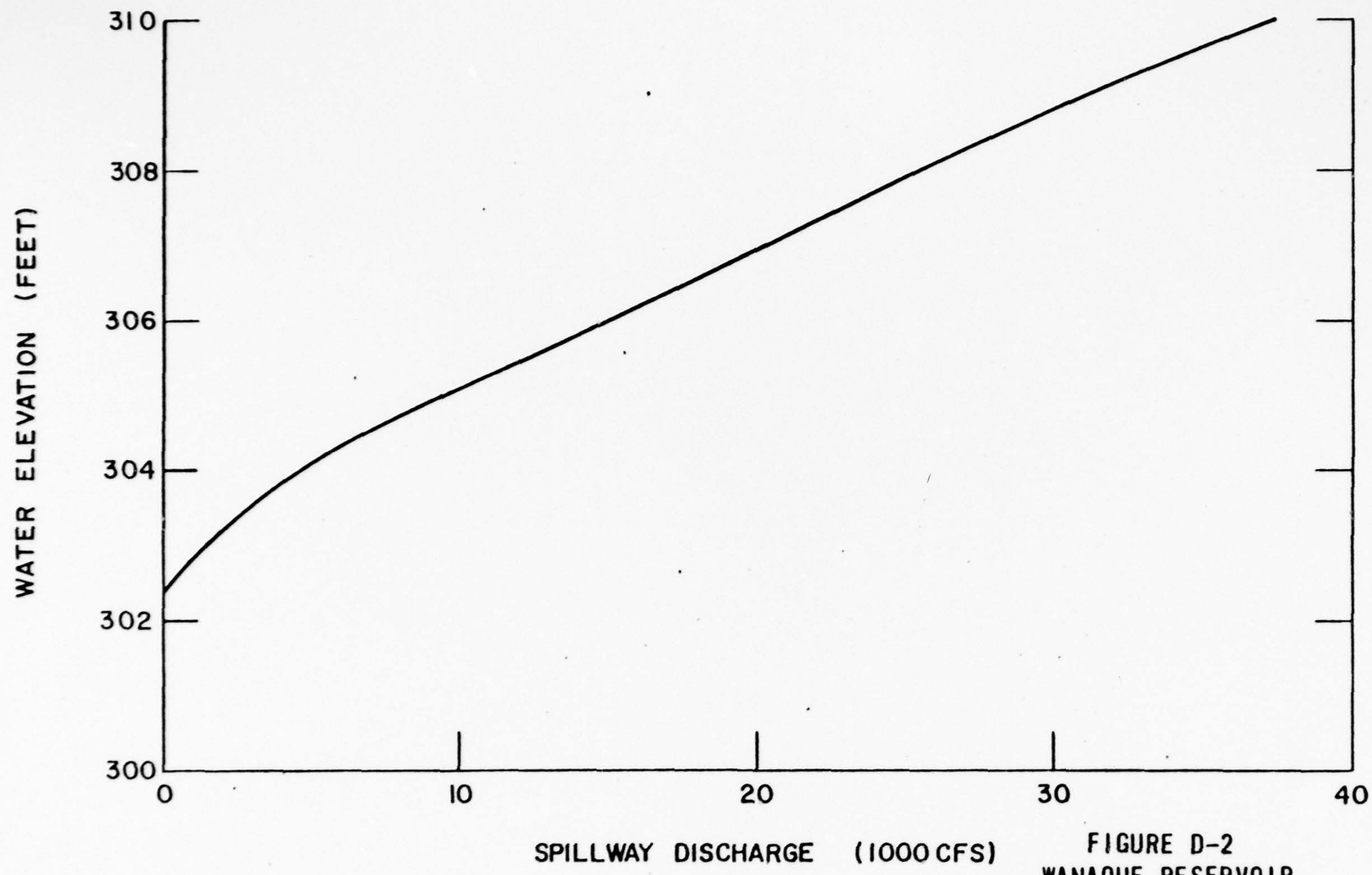


FIGURE D-2
WANAQUE RESERVOIR
OVERFLOW SPILLWAY
DISCHARGE RATING CURVE

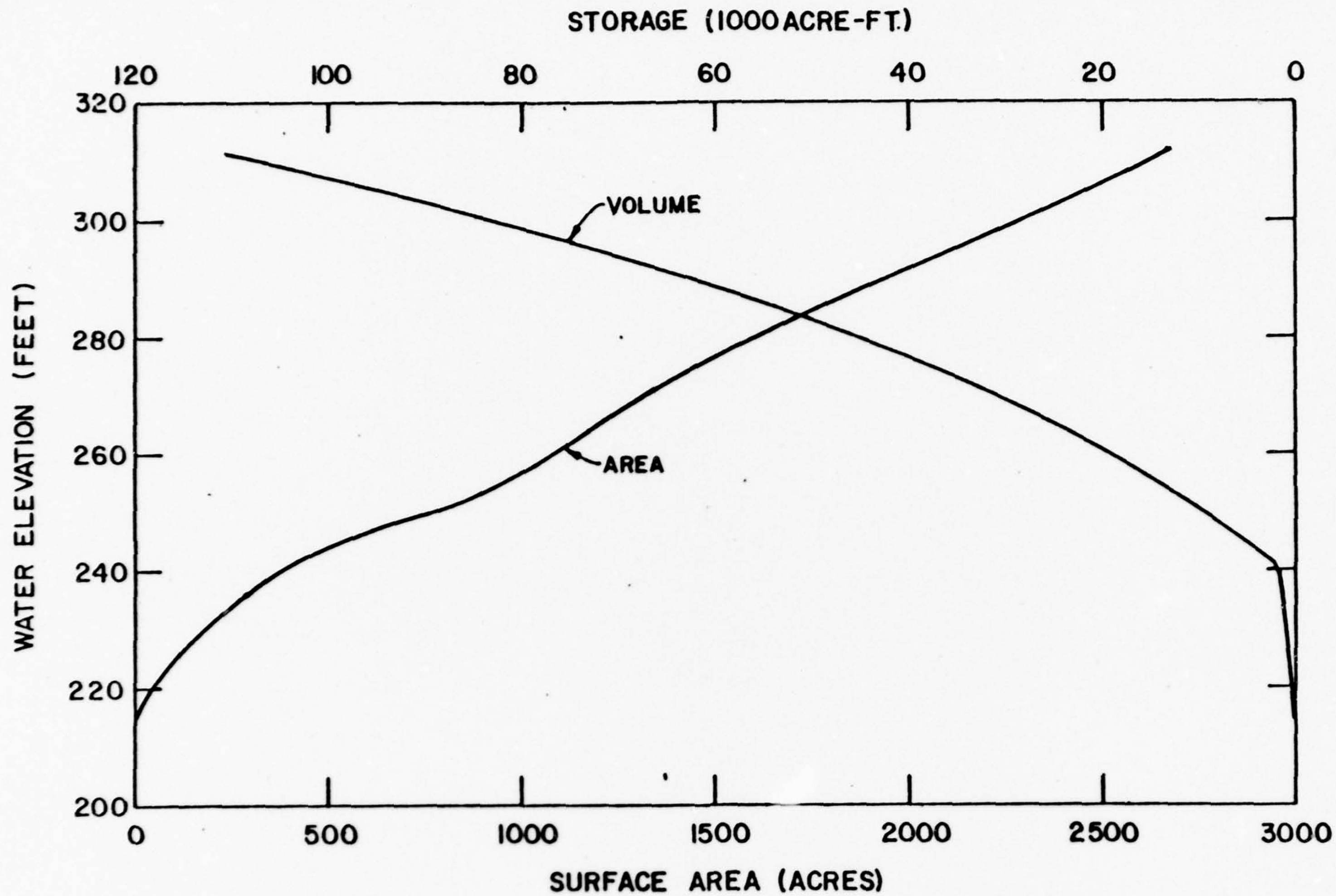


FIGURE D-3
WANAQUE RESERVOIR
AREA - CAPACITY CURVES

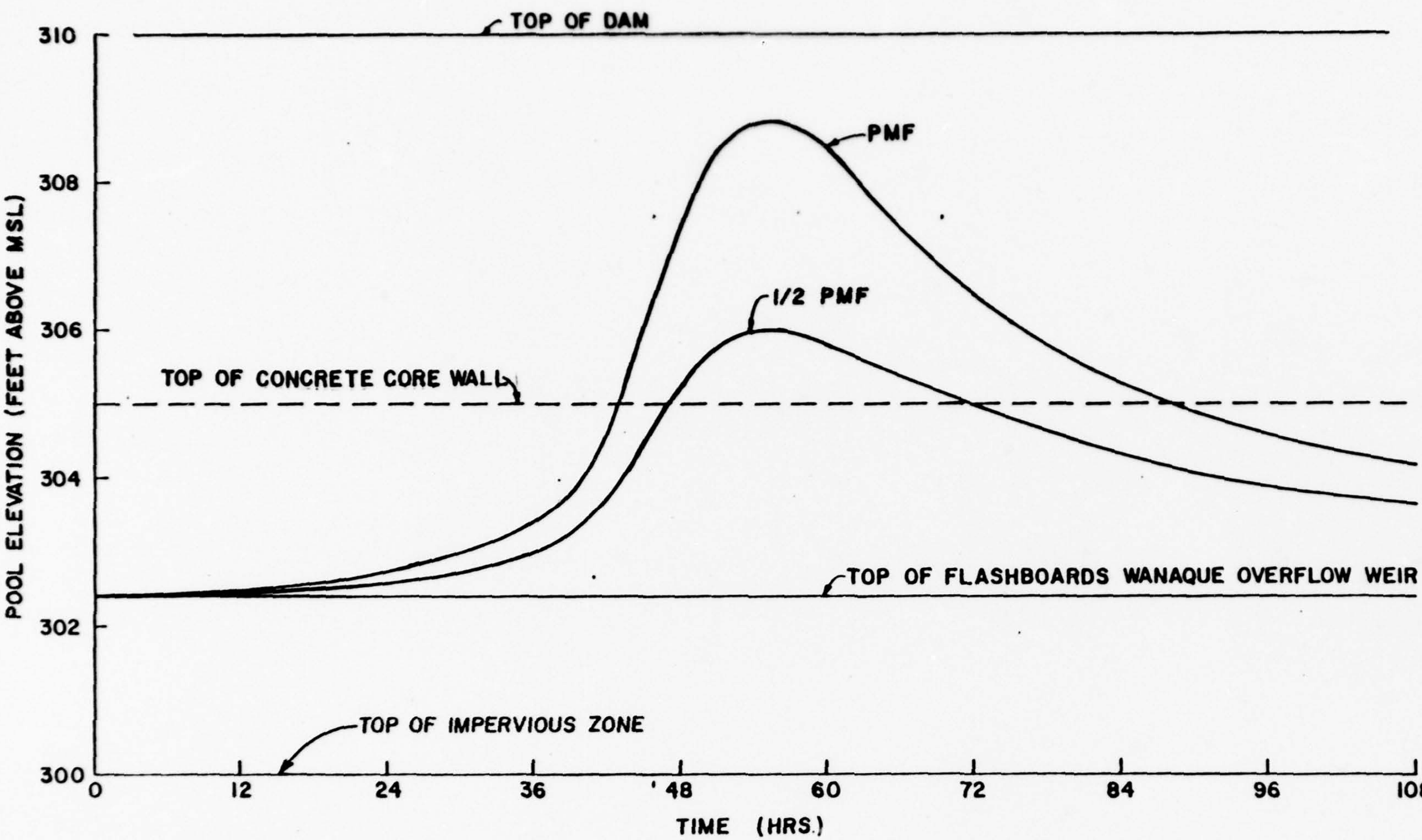


FIGURE D-4
FLOOD ROUTING THROUGH
WANAQUE RESERVOIR WITH
FLASHBOARDS IN PLACE

MIDVALE DAM

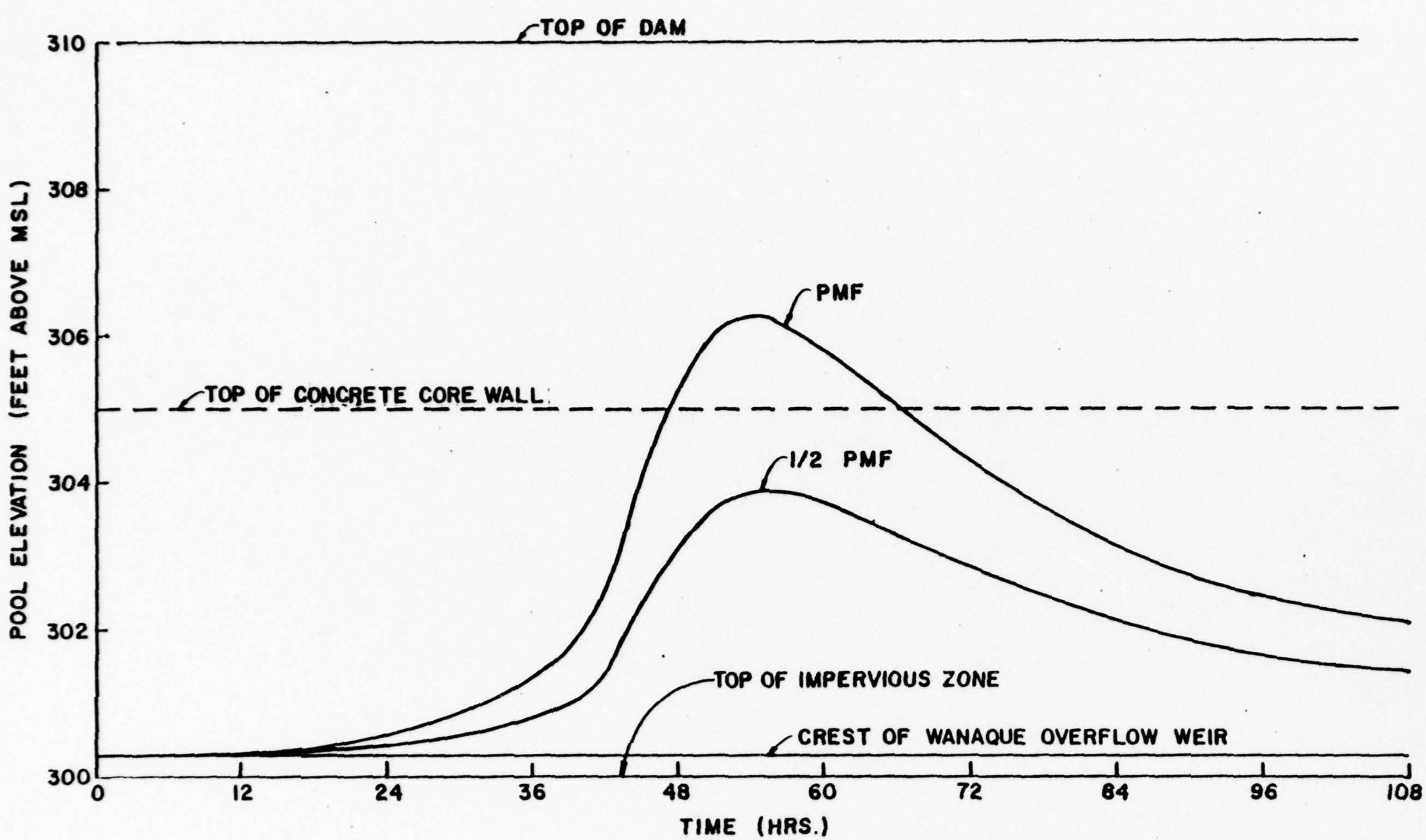


FIGURE D-5
FLOOD ROUTING THROUGH
WANAQUE RESERVOIR WITHOUT
FLASHBOARDS IN PLACE

MIDVALE DAM

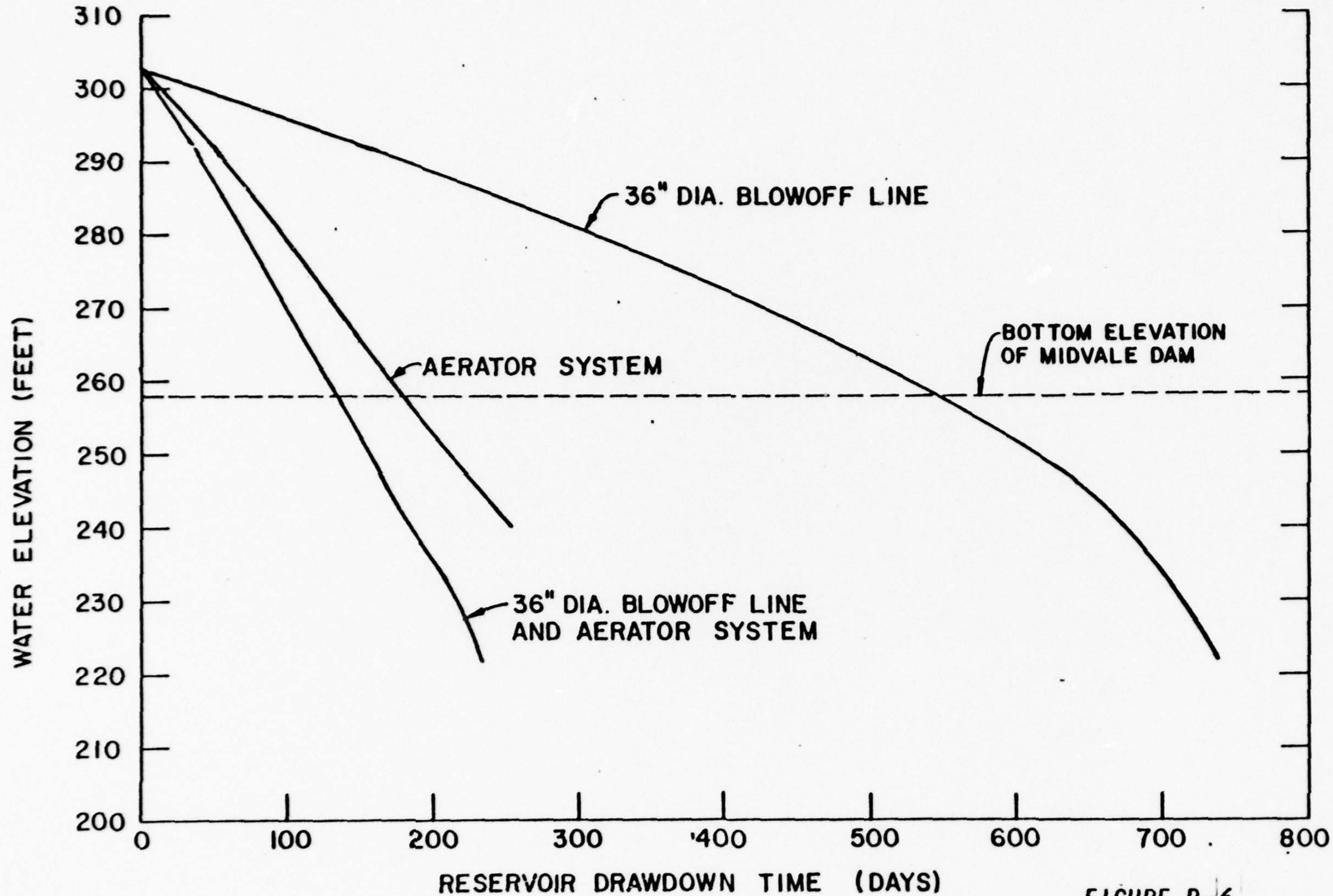


FIGURE D-6
WANAQUE RESERVOIR
TIME OF DRAWDOWN

APPENDIX E

PREVIOUS INSPECTION REPORTS
(Supplied by NJDWSC)

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

M E M O R A N D U M

TO: Dam Inspection File

FROM: Joseph Foley, Engineer

DATE: April 5, 1977

On March 31, 1977 Roscoe Jennings, Doug De Lorie and I inspected the dams at the Wanaque Reservoir; the following is a report on their conditions and recommendations on maintenance of same.

FURNACE ROAD DAM

Condition: There are trees and brush on the wet and dry sides of the dam and also a small swamp of apparently trapped water behind the dam.

Recommendations: The trees should be killed and removed using poison suitable for potable water.

MIDVALE DAM

Condition: Some trees are growing on the wet and dry sides of the dam. There is a small spring flowing from the foot of the dam at the north end. Wet spots and soft wet sand are also apparent at the foot of the dam. No sink holes or other indications of dam failure were apparent at this location. A sample of water from this spring and a sample from the reservoir were taken and anlyzed, the results are as follows:

Spring Water:	Specific conductivity	68
	pH	6.3
Reservoir Water:	Specific conductivity	102
	pH	6.9

The results indicate that this water is more likely to be ground water than reservoir water. (For additional information, please refer to a memo from Bob Wieland to George Destito dated May 3, 1976).

Recommendations: The trees on the dam should be killed and removed. The dam should also be checked periodically to be sure the spring is not a leak in the dam.

RAYMOND DAM

Condition: Excellent

SPILLWAY

Condition: Good, except that it was indicated by Ernie Restaino that there is a small leak in the spillway. I did not observe it because of the overflow. I will check it again when the reservoir goes down.

Recommendations: The leak in the spillway should be fixed when the reservoir goes down.

WOLF DEN DAM

Condition: There are trees and shrubs on both the wet and dry sides. There are small springs flowing from the low sections behind the dam. Some samples were also taken here and the results were that the water had a specific conductivity of 90 and a pH of 6.3, so this water is most likely ground water also.

Recommendations: I recommend that the trees and shrubs be removed.

GREEN SWAMP

#4 Dam

Condition: The general condition of the dam is good, although sections of the gunite surfacing are cracked and have fallen off (especially near the expansion joints), due to moisture that found its way under the guite. There was water running out of the drain but this flow was not excessive.

Recommendations: The cracked and loose gunite should be chipped away and replaced and at the expansion joints, the gunite should be chipped and tar poured in to allow expansion of the concrete.

#3 and #2A Dams

Condition: Both small dams are heavily wooded and there is a small swamp behind the #3 dam.

Recommendations: The only recommendation for these dams is that the trees be removed from both sides of the dams.

#2 Dam

Condition: This dam is in excellent condition, except around the expansion joints where the gunite is cracked due to the fact that no allowance was made for expansion when the guite was applied to the dam. There is also a swamp behind this dam, but this looks like a natural swamp.

Recommendations: The gunite at the expansion joints should be chipped away and tar poured in to allow expansion and any other cracks in the gunite should be chipped and repaired.

#1 Dam

Condition: There are trees and shrubs on both wet and dry sides of this dam. There is also a swamp behind the dam.

Recommendations: The dam should be cleared of trees and shrubs.

As a result of my research, so far on dam inspection, I received a booklet, "Supervision of Dams by State Authorities" published by the United States Committee on large dams, July 1966. This publication had little information on the actual inspection of dams but it did have some useful information such as: the function of dam supervision in New Jersey is performed by the Chief Engineer, Division of Water Policy and Supply, Department of Conservation and Economic development. Inspection of dams is done by the State at the State's own expense on the complaint of potential failure.

Additional information on dam inspection is also coming from the Corps of Engineers and the United States Committee on Large Dams.

JF:lk

cc: Dean C. Noll
Robert G. Wieland

NORTH JERSEY DISTRICT WATER SUPPLY COMMISSION

MEMORANDUM

May 3, 1976

TO: Chief George Destito

RE: Midvale Dam

After examining the wet area at the base of Midvale Dam, I present the following observations:

1. The area is fed by a number of very small low energy springs as far apart as 600'. Since the location is at a low point having long step slopes on three sides, it is normal for ground water to seep downhill through the soil and surface at the bottom in this fashion. If there was a leak through Midvale Dam, I would expect to see a significant boil at one or two points in close proximity. Thus, the evidence indicates that the water condition appear to be the product of natural conditions.

2. The area is drained by a intermittent brook, which shows on a topographical map (212E) dated March 12, 1920. The brook was located in the field and found to be substantially as it existed at that time. Thus, the wet area and the brook it feeds have been in existence some 56 years or more. In addition, the brook is clear and free running, which is preventing ponding. The marshy conditions cannot be readily eliminated.

3. A water sample taken in the marshy area and analyzed in the Lab proved inconclusive since shallow ground water has similar characteristics to reservoir water.

For your information, should questions again arise in the future regarding this area, I am attaching a copy of Acc. 3252, which shows the concrete core wall used in the construction of Midvale Dam. You will note that this is at least 4' thick and extends well into solid rock.

ROBERT G. WILLARD,
Engineer

RGW:lk
Attachment
cc: Dean C. Noll
Louis Longo

Report on Dam Inspection

WANAQUE PROJECT

Application No. 32.

Location 23.31.5.4.8 and nearby.

On March 23, 1928, the gates in the main dam were closed except for the passage of 27 m. g. d. through the blow-off, and on March 29, 1928, the water in the reservoir had risen 7 feet.

On March 29, 1928, in company with Mr. H. T. Critchlow, inspection was made of all of the dams in the Wanaque project.

Furnace Road dam was found to be about 50 per cent complete.

Post Brook Diversion dam, weir and control house were complete except for closing a small breach which was left in the dam for stream control, and installation of recording gage in the control house.

Wanaque Main dam.

Midvale Dam.

Overflow Weir.

Wolf Den Dam, and

Green Swamp Dams Nos. 1, 2, 3 and 4 were complete and were given final inspection.

The construction of all dams has been done in accordance with the approved plans and in a thoroughly workmanlike and satisfactory manner.

John N. Brooks

John N. Brooks
Hydraulic Engineer.

C 7/30

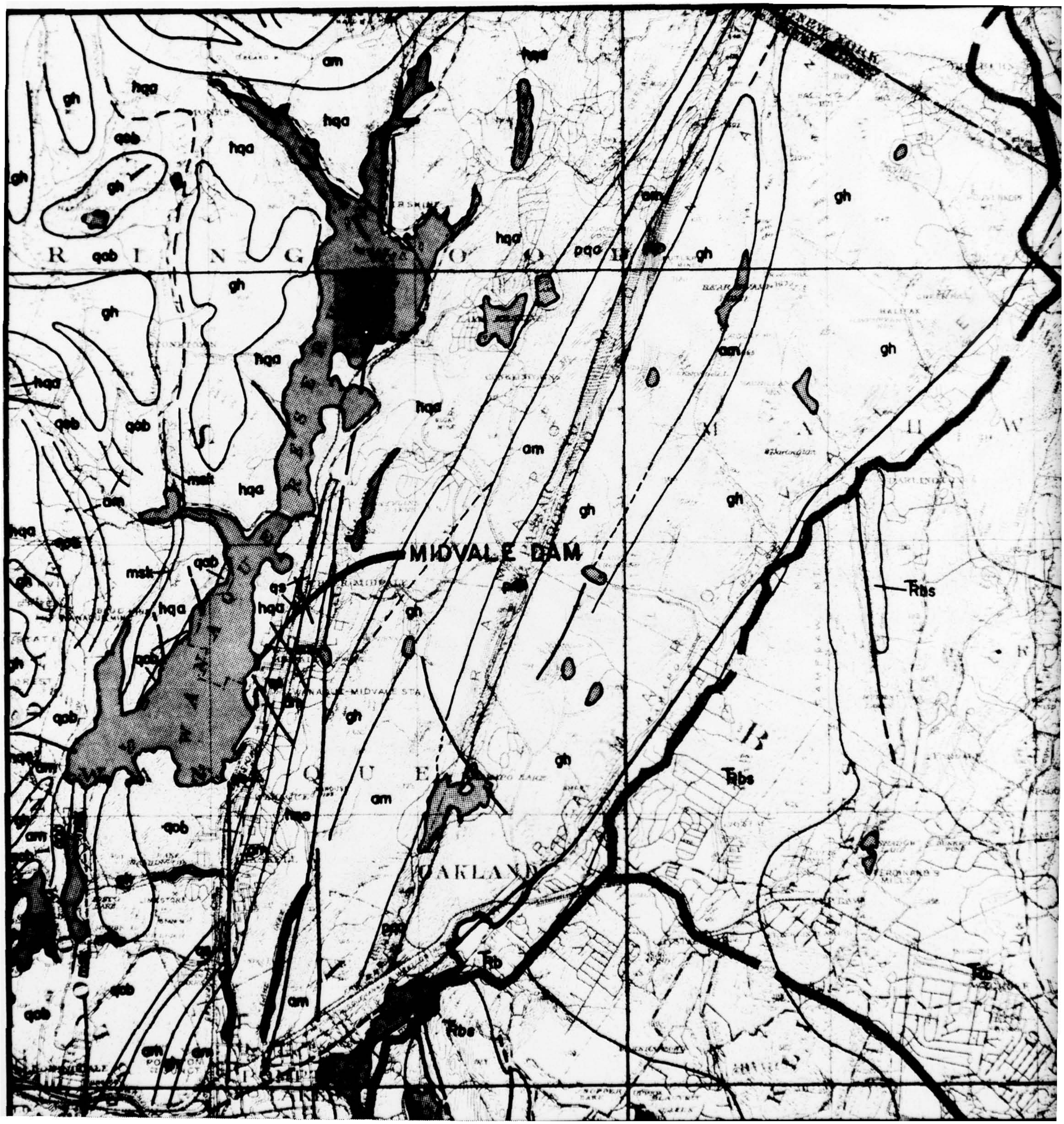
Trenton, N. J.

March 30, 1928.

(New Jersey - Dept. of Environmental Protection)

APPENDIX F

REGIONAL GEOLOGIC MAP


MIDVALE DAM
OAKLAND

LEGEND

TRIASSIC

TRb	BRUNSWICK FORMATION
TRbs	BASALT FLOWS

PRECAMBRIAN

gh	MOSTLY HORNBLENDE GRANITE AND GRANITE GNEISS
am	AMPHIBOLITE
pqo	PYROXENE GNEISS; MAINLY QUARTZ-OLIGOCLASE - CLINOPYROXENE GNEISS
hqa	PYROXENE GNEISS; MAINLY QUARTZ-ANDESINE GNEISS WITH BOTH ORTHO-AND CLINOPYROXENE
qo	QUARTZ-OLIGOCLASE-GNEISS
qob	QUARTZ-OLIGOCLASE-BIOTITE GNEISS
qs	SILLIMANITE GNEISS
msk	MARBLE AND SKARN.

CONTACT LINE

FAULT LINE

NOTES:

1. THE PRECAMBRIAN MAP UNITS REPRESENT GENERALIZED GROUPINGS OF ROCK TYPES BASED MAINLY ON MINERAL COMPOSITION. THERE IS MUCH LOCAL VARIATION IN THE MINERAL COMPOSITION.
2. THE CONTACT LINES AND FAULT LINE SHOWN ON THE DRAWING ARE DASHED WHERE INFERRED.

SOURCE:

NEW JERSEY GEOLOGICAL SURVEY TOPOGRAPHIC SERIES AND GEOLOGIC OVERLAY SHEETS 23.

1 0 1 2

SCALE IN MILES

APPENDIX F

REGIONAL GEOLOGIC MAP SHOWING DAM LOCATION

APPENDIX G

REFERENCES

APPENDIX G

REFERENCES

1. Recommended Guidelines for Safety Inspection of Dams, Appendix D, (Washington, D.C., Department of the Army, Office of the Chief of Engineers).

2. North Jersey District Water Supply Commission - Report 1925, (Newark, N.J., Office of the Commission), 1925.

3. Public Works, Vol. 54, No. 5, May 1923.

4. Water Resources Data for New Jersey, Part 1, Surface Water Records, United States Department of the Interior, Geologic Survey.

5. HEC-1 Flood Hydrograph Package, Hydrologic Engineering Center, Corps of Engineers, January, 1973.

6. Daily Reservoir Water Level and Discharge Record Files from October 1950 to date, owned by the NJDWSC.

7. Water Resources Data for New Jersey, Part 1, Surface Water Records, USGS, Department of the Interior.

8. Passaic River Basin - New Jersey and New York Survey Report for Water Resources, New York District Corps of Engineers, June 1972.

APPENDIX H

CONDITIONS

APPENDIX H

CONDITIONS

This report is based on a visual inspection of the dam, a review of available engineering data and a hydrologic analysis performed during Phase I Investigation as set forth in the "Recommended Guidelines for Safety Inspection of Dams", as modified by the contract between the U.S. Corps of Engineers and Gilbert Associates, Inc., Contract No. DACW61-78-C-0114.

The foregoing review, inspection, and analysis are by their nature limited in scope. It is possible that hazardous conditions exist and that conditions exist which with time might develop into safety hazards and that these conditions are not detectable by means of the aforesaid review, inspection, and analysis. Accordingly Gilbert Associates, Inc. cannot and does not warrant or represent that conditions which are hazardous do not exist, or that conditions do not exist which with time might develop into safety hazards.

As required by the Corps of Engineers the terms "good", "fair", "poor", "condition" have been used in this Report to characterize the information obtained from the aforesaid review, inspection, and analysis. The definitions of these terms as used are:

"good condition" - minor studies or remedial measures are required.

"fair conditon" - sizeable studies or remedial measures are required due to deficiencies which could be hazardous depending on conditions. Immediate attention is required.

"poor condition" - major studies or remedial measures are required due to deficiencies which could be hazardous depending on conditions. Immediate studies or corrective action is required.

APPENDIX I

Corps of Engineers
STANDARD STUDIES
(Source: Reference 1)

Reclamation and Soil Conservation Service. Many other agencies, educational facilities and private consultants can also provide expert advice. Regardless of where such expertise is based, the qualification of those individuals offering to provide it should be carefully examined and evaluated.

4.3.4. Freeboard Allowances. Guidelines on specific minimum freeboard allowances are not considered appropriate because of the many factors involved in such determinations. The investigator will have to assess the critical parameters for each project and develop its minimum requirement. Many projects are reasonably safe without freeboard allowance because they are designed for overtopping, or other factors minimize possible overtopping. Conversely, freeboard allowances of several feet may be necessary to provide a safe condition. Parameters that should be considered include the duration of high water levels in the reservoir during the design flood; the effective wind fetch and reservoir depth available to support wave generation; the probability of high wind speed occurring from a critical direction; the potential wave runup on the dam based on roughness and slope; and the ability of the dam to resist erosion from overtopping waves.

4.4. Stability Investigations. The Phase II stability investigations should be compatible with the guidelines of this paragraph.

4.4.1. Foundation and Material Investigations. The scope of the foundation and materials investigation should be limited to obtaining the information required to analyze the structural stability and to investigate any suspected condition which would adversely affect the safety of the dam. Such investigations may include borings to obtain concrete, embankment, soil foundation, and bedrock samples; testing specimens from these samples to determine the strength and elastic parameters of the materials, including the soft seams, joints, fault gouge and expansive clays or other critical materials in the foundation; determining the character of the bedrock including joints, bedding planes, fractures, faults, voids and caverns, and other geological irregularities; and installing instruments for determining movements, strains, suspected excessive internal seepage pressures, seepage gradients and uplift forces. Special investigations may be necessary where suspect rock types such as limestone, gypsum, salt, basalt, claystone, shales or others are involved in foundations or abutments in order to determine the extent of cavities, piping or other deficiencies in the rock foundation. A concrete core drilling program should be undertaken only when the existence of significant structural cracks is suspected or the general qualitative condition of the concrete is in doubt. The tests of materials will be necessary only where such data are lacking or are outdated.

4.4.2. Stability Assessment. Stability assessments should utilize in situ properties of the structure and its foundation and pertinent geologic

information. Geologic information that should be considered includes groundwater and seepage conditions; lithology, stratigraphy, and geologic details disclosed by borings, "as-built" records, and geologic interpretation; maximum past overburden at site as deduced from geologic evidence; bedding, folding and faulting; joints and joint systems; weathering; slickensides, and field evidence relating to slides, faults, movements and earthquake activity. Foundations may present problems where they contain adversely oriented joints, slickensides or fissured material, faults, seams of soft materials, or weak layers. Such defects and excess pore water pressures may contribute to instability. Special tests may be necessary to determine physical properties of particular materials. The results of stability analyses afford a means of evaluating the structure's existing resistance to failure and also the effects of any proposed modifications. Results of stability analyses should be reviewed for compatibility with performance experience when possible.

4.4.2.1. Seismic Stability. The inertial forces for use in the conventional equivalent static force method of analysis should be obtained by multiplying the weight by the seismic coefficient and should be applied as a horizontal force at the center of gravity of the section or element. The seismic coefficients suggested for use with such analyses are listed in Figures 1 through 4. Seismic stability investigations for all high hazard category dams located in Seismic Zone 4 and high hazard dams of the hydraulic fill type in Zone 3 should include suitable dynamic procedures and analyses. Dynamic analyses for other dams and higher seismic coefficients are appropriate if in the judgment of the investigating engineer they are warranted because of proximity to active faults or other reasons. Seismic stability investigations should utilize "state-of-the-art" procedures involving seismological and geological studies to establish earthquake parameters for use in dynamic stability analyses and, where appropriate, the dynamic testing of materials. Stability analyses may be based upon either time-history or response spectra techniques. The results of dynamic analyses should be assessed on the basis of whether or not the dam would have sufficient residual integrity to retain the reservoir during and after the greatest or most adverse earthquake which might occur near the project location.

4.4.2.2. Clay Shale Foundation. Clay shale is a highly overconsolidated sedimentary rock comprised predominantly of clay minerals, with little or no cementation. Foundations of clay shales require special measures in stability investigations. Clay shales, particularly those containing montmorillonite, may be highly susceptible to expansion and consequent loss of strength upon unloading. The shear strength and the resistance to deformation of clay shales may be quite low and high pore water pressures may develop under increase in load. The presence of slickensides in clay shales is usually an indication of low shear stength. Prediction

of field behavior of clay shales should not be based solely on results of conventional laboratory tests since they may be misleading. The use of peak shear strengths for clay shales in stability analyses may be unconservative because of nonuniform stress distribution and possible progressive failures. Thus the available shear resistance may be less than if the peak shear strength were mobilized simultaneously along the entire failure surface. In such cases, either greater safety factors or residual shear strength should be used.

4.4.3. Embankment Dams.

4.4.3.1. Liquefaction. The phenomenon of liquefaction of loose, saturated sands and silts may occur when such materials are subjected to shear deformation or earthquake shocks. The possibility of liquefaction must presently be evaluated on the basis of empirical knowledge supplemented by special laboratory tests and engineering judgment. The possibility of liquefaction in sands diminishes as the relative density increases above approximately 70 percent. Hydraulic fill dams in Seismic Zones 3 and 4 should receive particular attention since such dams are susceptible to liquefaction under earthquake shocks.

4.4.3.2. Shear Failure. Shear failure is one in which a portion of an embankment or of an embankment and foundation moves by sliding or rotating relative to the remainder of the mass. It is conventionally represented as occurring along a surface and is so assumed in stability analyses, although shearing may occur in a zone of substantial thickness. The circular arc or the sliding wedge method of analyzing stability, as pertinent, should be used. The circular arc method is generally applicable to essentially homogeneous embankments and to soil foundations consisting of thick deposits of fine-grained soil containing no layers significantly weaker than other strata in the foundation. The wedge method is generally applicable to rockfill dams and to earth dams on foundations containing weak layers. Other methods of analysis such as those employing complex shear surfaces may be appropriate depending on the soil and rock in the dam and foundation. Such methods should be in reputable usage in the engineering profession.

4.4.3.3. Loading Conditions. The loading conditions for which the embankment structures should be investigated are (I) Sudden drawdown from spillway crest elevation or top of gates, (II) Partial pool, (III) Steady state seepage from spillway crest elevation or top of gate elevation, and (IV) Earthquake. Cases I and II apply to upstream slopes only; Case III applies to downstream slopes; and Case IV applies to both upstream and downstream slopes. A summary of suggested strengths and safety factors are shown in Table 4.

TABLE 4

FACTORS OF SAFETY ≠

Case	Loading Condition	Factor of Safety	Shear ≠≠ Strength	Remarks
I	Sudden drawdown from spillway crest or top of gates to minimum drawdown elevation.	1.2*	Minimum composite of R and S shear strengths See Figure 5.	Within the drawdown zone submerged unit weights of materials are used for computing forces resisting sliding and saturated unit weights are used for computing forces contributing to sliding.
II	Partial pool with assumed horizontal steady seepage saturation.	1.5	$\frac{R+S}{2}$ for $R < S$ S for $R > S$	Composite intermediate envelope of R and S shear strengths. See Figure 6.
III	Steady seepage from spillway crest or top of gates with $K_h/K_v = 9$ assumed**	1.5	Same as Case II	
IV	Earthquake (Cases II and III with seismic loading)	1.0	***	See Figures 1 through 4 for Seismic Coefficients.

≠ Not applicable to embankments on clay shale foundation. Experience has indicated special problems in determination of design shear strengths for clay shale foundations and acceptable safety factors should be compatible with the confidence level in shear strength assumptions.

≠≠ Other strength assumptions may be used if in common usage in the engineering profession.

* The safety factor should not be less than 1.5 when drawdown rate and pore water pressure developed from flow nets are used in stability analyses.

** K_h/K_v is the ratio of horizontal to vertical permeability. A minimum of 9 is suggested for use in compacted embankments and alluvial sediments.

*** Use shear strength for case analyzed without earthquake. It is not necessary to analyze sudden drawdown for earthquake loading. Shear strength tests are classified according to the controlled drainage conditions maintained during the test. R tests are those in which specimen drainage is allowed during consolidation (or swelling) under initial stress conditions, but specimen drainage is not allowed during application of shearing stresses. S tests allow full drainage during initial stress application and shearing is at a slow rate so that complete specimen drainage is permitted during the complete test.

4.4.3.4. Safety Factors. Safety factors for embankment dam stability studies should be based on the ratio of available shear strength to developed shear strength, S_D:

$$S_D = \frac{C}{F.S.} + \sigma \frac{\tan \phi}{F.S.} \qquad (1)$$

C = cohesion

ϕ = angle of internal friction

σ = normal stress

The factors of safety listed in Table 4 are recommended as minimum acceptable. Final accepted factors of safety should depend upon the degree of confidence the investigating engineer has in the engineering data available to him. The consequences of a failure with respect to human life and property damage are important considerations in establishing factors of safety for specific investigations.

4.4.3.5. Seepage Failure. A critical uncontrolled underseepage or through seepage condition that develops during a rising pool can quickly reduce a structure which was stable under previous conditions, to a total structural failure. The visually confirmed seepage conditions to be avoided are (1) the exit of the phreatic surface on the downstream slope of the dam and (2) development of hydrostatic heads sufficient to create in the area downstream of the dam sand boils that erode materials by the phenomenon known as "piping" and (3) localized concentrations of seepage along conduits or through pervious zones. The dams most susceptible to seepage problems are those built of or on pervious materials of uniform fine particle size, with no provisions for an internal drainage zone and/or no underseepage controls.

4.4.3.6. Seepage Analyses. Review and modifications to original seepage design analyses should consider conditions observed in the field inspection and piezometer instrumentation. A seepage analysis should consider the permeability ratios resulting from natural deposition and from compaction placement of materials with appropriate variation between horizontal and vertical permeability. An underseepage analysis of the embankment should provide a critical gradient factor of safety for the maximum head condition of not less than 1.5 in the area downstream of the embankment.

$$F.S = i_c/i = \frac{H_c/D_b}{H/D_b} = D_b \frac{(\gamma_m - \gamma_w)}{H \gamma_w} \qquad (2)$$

i_c = Critical gradient

i = Design gradient

H = Uplift head at downstream toe of dam measured above tailwater

H_c = The critical uplift

D_b = The thickness of the top impervious blanket at the downstream toe of the dam

γ_m = The estimated saturated unit weight of the material in the top impervious blanket

γ_w = The unit weight of water

Where a factor of safety less than 1.5 is obtained the provision of an underseepage control system is indicated. The factor of safety of 1.5 is a recommended minimum and may be adjusted by the responsible engineer based on the competence of the engineering data.

4.4.4. Concrete Dams and Appurtenant Structures.

4.4.4.1. Requirements for Stability. Concrete dams and structures appurtenant to embankment dams should be capable of resisting overturning, sliding and overstressing with adequate factors of safety for normal and maximum loading conditions.